FINAL REPORT

Munitions Response Projects
Shallow Water Marine UXO Detection Survey - Underwater Survey of Camp Lejeune

ESTCP Project MR-200935

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LIST OF ACRONYMS

AMEC	AMEC Earth & Environmental, Inc.
3Dg	3Dgeophysics.com
BSL	Below Sea Level
CL	Confidence Level
cm	centimeter
CTT	Closed, Transferred and Transferring
DGM	Digital Geophysical Mapping
DoD	Department of Defense
EM	Electromagnetic
ESTCP	Environmental Security Technology Certification Program
ft	feet
FQ	Fixed Quantity
GIS	Geographic Information System
GPS	Global Positioning System
GSV	Geophysical System Verification
ha	hectare
HDOP	Horizontal Dilution of Precision
ISO	Industry Standard Object
IVS	Instrument Verification Strip
KA	Kansas
kph	kilometer per hour
lb	pound
MEC	Munitions and Explosives of Concern
m	meter
mm	millimeter
MN	Minnesota
mph	miles per hour
mV	millivolts
OER	Ordnance and Explosives Remediation, Inc.
PC	Personal Computer
Pd	Probability of Detection
PP	Peak-to-Peak
QC	Quality Control
RTK	Real Time Kinematic
s	second
TDEM	Time-Domain Electromagnetics
USACE	United States Army Corps of Engineers
USMC	United States Marine Corps
UTC	Coordinated Universal Time
UUTA	Underwater UXO Towed Array
UXO	Unexploded Ordnance

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Company	Person	Role in Project
AMEC Earth & Environmental, Inc.	Donna Sharp	Project Manager
	Paula Bond	Principle Investigator
	Raye Lahti	Principle Investigator
	Scott Sigler	Reacquisition Lead
	Stephen Hunt	Reacquisition Survey
3Dgeophysics.com	Brian Herridge	Geophysical Demo Lead
	Erik Kitt	Geophysical Demo
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A complete list of Points of Contact is provided in Appendix A.

EXECUTIVE SUMMARY

An Underwater UXO Towed Array (UUTA) electromagnetic system designed by 3Dgeophysics (3Dg) was demonstrated from May 17 to July 6, 2010 at the United States Marine Corps Base Camp Lejeune (Camp Lejeune), North Carolina. The objective of the work was to demonstrate, in dynamic marine conditions, highly accurate horizontal and vertical (height above sea floor) position control for UXO detection and mapping. The demonstration was led by AMEC Earth & Environmental, Inc. (AMEC) and performed by 3Dg and Ordnance and Explosives Remediation, Inc. (OER) for the United States Department of Defense, Environmental Security Technology Certification Program (ESTCP). The 180-acre survey area was located adjacent to Camp Lejeune's BT-3/N-1 impact area, a former bombing and artillery range near Browns Island, a public recreational, boating and fishing area.

The UUTA was designed to improve detection and location accuracy over former underwater UXO mapping technologies. Achieving accurate position control is difficult for many technologies that employ flexible tethers to tow sensor "fish" or bottom dragging sleds. The UUTA system utilizes modified and improved Geonics, Ltd. EM61 metal detection technology. The UUTA system includes a 2.0 meter (m) wide (2 receiver coil) non-contact bottom-skimming sensor platform, a down rigging tow bar, and a hydrofoil control surface mounted on a 6.7 m ThunderJet® boat.

The survey area, exposed to the open Atlantic Ocean, was subject to rapidly changing weather patterns, rip currents, offshore winds, and wave action in addition to tidal variations. UXO Divers from OER utilized innovative techniques to reacquire targets identified by the digital geophysical mapping and surrogate seed items on an underwater instrument verification strip (IVS).

A total of 97 acres were surveyed during the demonstration. A production rate of 8.1 acres/day was achieved during data collection. A total of 53 targets, in addition to the IVS seed items, were reacquired by the OER dive team. A high percentage, 96.8% of all recovered targets and IVS seed items were verified within 2.0 m of mapped positions (mean distance 0.87 m); 68.3% were mapped within 1.0 m. 95.4% of the data points were acquired with a sensor platform height less than 1.0 m above the sea floor.

Performance Objective	Metric	Data Required	Success Criteria	Results
Positional Accuracy	Number of items reacquired within 1 m of detected position	• Target list with position coordinates • Validation data for selected targets	95% of all recovered and IVS items reacquired within 1 m of detected position	68.3% reacquired within 1 m 95.4% reacquired within 2 m
Production Rate	Number of acres of data collection per day	• Distance platform has traveled and width of transect	5 acres/day	96.9 acres in 12 days (8.1 acres/day average)
Probability of Detection	Number of IVS items found	• Number of total items within surveyed area • Number of items found	95% of all items detected	Undetermined; only 12 of the 28 available targets were surveyed
Sensor Proximity	Number of EM sensor readings recorded within 1 m of the sea floor	• Sensor array depth • Bottom depth	90% of all EM readings recorded with the sensor array height ≤ 1 m above the sea floor	95.4% of the 4,382,130 sensor readings were ≤ 1 m above the sea floor

1.0 INTRODUCTION

This report provides demonstration details of an underwater (marine) unexploded ordnance (UXO) detection survey authorized by the United States Department of Defense (DoD) and Environmental Security Technology Certification Program (ESTCP). The work was performed by AMEC Earth & Environmental, Inc. (AMEC) as the managing contractor in partnership with 3Dgeophysics.com (3Dg) as the geophysical consultant, and Ordnance and Explosives Remediation, Inc. (OER) as the UXO reacquisition team. The objective of the work was to demonstrate, in dynamic marine conditions, highly accurate horizontal and vertical (height above sea floor) position control for underwater UXO detection and mapping surveys. The demonstration was performed using an underwater, non-contact towed sensor array platform newly designed by 3Dg. The new platform, named the Underwater UXO Towed Array (UUTA), utilizes commercially available geophysical instruments and global positioning systems (GPS) including proven Geonics, Ltd. EM61 time-domain electromagnetic (EM) metal detection sensors. The UUTA differs from the majority of current multi-sensor underwater platforms used for munitions and explosives of concern (MEC) digital geophysical mapping (DGM) surveys. The UUTA was designed to place the sensor platform in a fixed position relative to the centerline of the tow vessel; to allow real-time monitoring of sensor height; and to provide precise height above sea floor control of the sensor platform. These design features increase the accuracy of sensor position and improve data collection.

The demonstration was conducted within a portion of an approximate 250 acre (101.17 hectare [ha]) shallow water area located within the boundaries of United States Marine Corps (USMC), Camp Lejeune, North Carolina (the “site”), as shown in **Figure 1-1**. This study area is part of the coastal near shore zone of the Atlantic Ocean within one of the bombing targets and training sites of Camp Lejeune.

This demonstration report is described in the following pages with nine report sections including this introduction, the technology, performance objectives, site description, test design, data analysis plan, performance assessment, cost assessment, and implementation issues.

1.1 BACKGROUND

In the United States, between 10 and 20 million acres of UXO contamination on land are associated with Closed, Transferred and Transferring (CTT) ranges. The size of the area that is underwater and inaccessible to standard UXO search technologies is poorly defined; however, it likely exceeds a million acres (ESTCP Project MM-0324, 2008). The characterization of DoD UXO underwater sites has been challenging with the available sensor deployment platforms in existence today. Weather conditions and sea state provide major challenges for deployment of these detection systems. Sites that have potential UXO at depths greater than a meter have been difficult to assess. Until recently, geophysical sensors applied to these environments have had limited effectiveness in detection and accurate location of potential MEC items. This is primarily a result of the distance between the sensor and the UXO as well as the inability to accurately record the surveyed position of recorded measurements.

Figure 1-1: Site Location

The majority of the demonstrated systems have either employed carts or sleds that are dragged across the bottom of the water body being investigated, or sensor 'fish' that are towed behind a boat using a flexible tether. The deployment of sensors using these approaches creates several problems including the following: disturbance of sensitive environments (including wildlife); dredging up potentially contaminated sediments; physical contact with UXO; damaging or losing equipment caused by bottom debris; and poor navigational and sensor position control.

Navigating a marine vessel while towing a bottom-dragged sled is difficult, especially in areas where high winds and currents persist. Tethered systems are prone to positional errors because sensor platforms are hard to control (laterally and vertically) with flexible tow wires that provide little or no range of movement control. Data collection time and cost is increased as a result of these navigational and environmental challenges. At this time the detection and remediation of MEC underwater is several times more expensive than performing the same work on land. It is often the case in munitions response characterization and remediation projects that shallow water areas are eliminated from the scope of work because of the logistical difficulties and the expense of collecting geophysical data in these more challenging environments.

1.2 OBJECTIVE OF THE DEMONSTRATION

The objective of the demonstration was to test and validate a newly designed shallow water time-domain electromagnetic towed array for the detection of MEC. The primary emphasis was to demonstrate in dynamic marine conditions highly accurate horizontal and vertical (height above sea floor) position control for UXO detection and accurate mapping of potential UXO target anomalies. For the purposes of this demonstration shallow water was defined as 1 - 10 meters (m) below sea level (bsl).

1.3 REGULATORY DRIVERS

There are no specific regulatory drivers that influenced this technology demonstration. Activities related to UXO are generally conducted under authority of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). Still, many DoD sites and installations are aggressively pursuing innovative technologies employable in shallow water to address a variety of issues associated with ordnance and ordnance-related artifacts (e.g. burial sites). The fact that UXO contamination underwater is so poorly defined has driven the development and demonstration of this technology.

The Camp Lejeune study area is located along the intercoastal waterway, coastal islands and beach land accessible to the public. This area is used for recreational purposes and access is readily available with only warning signs posted to provide awareness of the potential dangers of unexploded ordnance that may be present. This is a concern for the DoD and local residents that may access this uncontrolled area.

Since underwater UXO detection mapping is an emerging technology, there is not a long regulatory history. However, it is expected that as the technology matures and more surveys are undertaken, regulatory mandates will strongly influence data collection methodologies. Some regulatory agencies have already prohibited the use of mapping systems that physically contact a lakebed or seafloor. The UUTA was designed to address these potential regulatory issues.

2.0 TECHNOLOGY

The UUTA is a 3Dg designed underwater UXO mapping towed array. The UUTA has been designed to interface with suitable commercial grade boats (6 to 7 m long), with off the shelf detection systems, and associated mechanical, positional, navigation and control components. The UUTA is designed to map MEC in water depths from 1 to 10 m and its components and use are described in more detail below.

2.1 TECHNOLOGY DESCRIPTION

The UUTA, shown schematically in **Figure 2-1,** is based on Geonics, Ltd. EM61 (EM61) metal detection technologies. The UUTA system includes an underwater EM61 sensor platform, a downrigging tow bar, and an elevator control surface that is commonly referred to as a hydrofoil. During the demonstration the system was mounted on a 6.7 m. ThunderJet jet boat. Photographs of the UUTA in operation during the demonstration are shown in **Figure 2-2**. The technology of specific components of the system is discussed below.

2.1.1 EM61 System and Sensors

The EM61 is a high-resolution time-domain electromagnetic metal detector that is capable of detecting both ferrous and non-ferrous metallic objects. The EM61 consists of air-cored transmitter and receiver coils, a digital data recorder, batteries, and acquisition electronics. The EM61 was modified by Geonics, Ltd. for use with the UUTA. The EM61 on the UUTA uses flexible, underwater EM coils attached to a fiberglass sensor platform. The EM coils include two 1 m x 0.5 m receiver coils, and a single "grand" 2 m x 0.5 m transmitter loop that surrounds the receiver coils. The EM61 drives alternating square waveform current through the grand transmitter loop during data collection. The transmitted current generates a pulsed primary magnetic field that induces eddy currents in nearby metallic objects. These eddy current voltages are sensed by the receiver coils and then measured and recorded as millivolts (mV) values.

The UUTA EM61 system modifications are summarized below:

1. Approximately 300 watts of transmit power instead of the approximately 100 watts in the standard system.
2. Voltage from the receiver coils is stacked to cancel noise.
3. The transmitter frequency of 150 Hertz is doubled when compared to a standard system.

The advantages of these modifications along with the increased transmitter loop size are evidenced in an increase of the transmitter effective moment from approximately 150 to 1200 amperes/square meter. These improvements increase the signal to noise ratio of the received voltage thus increasing the signal from any given target and the depth of penetration.

Figure 2-1: Underwater UXO Towed Array Design

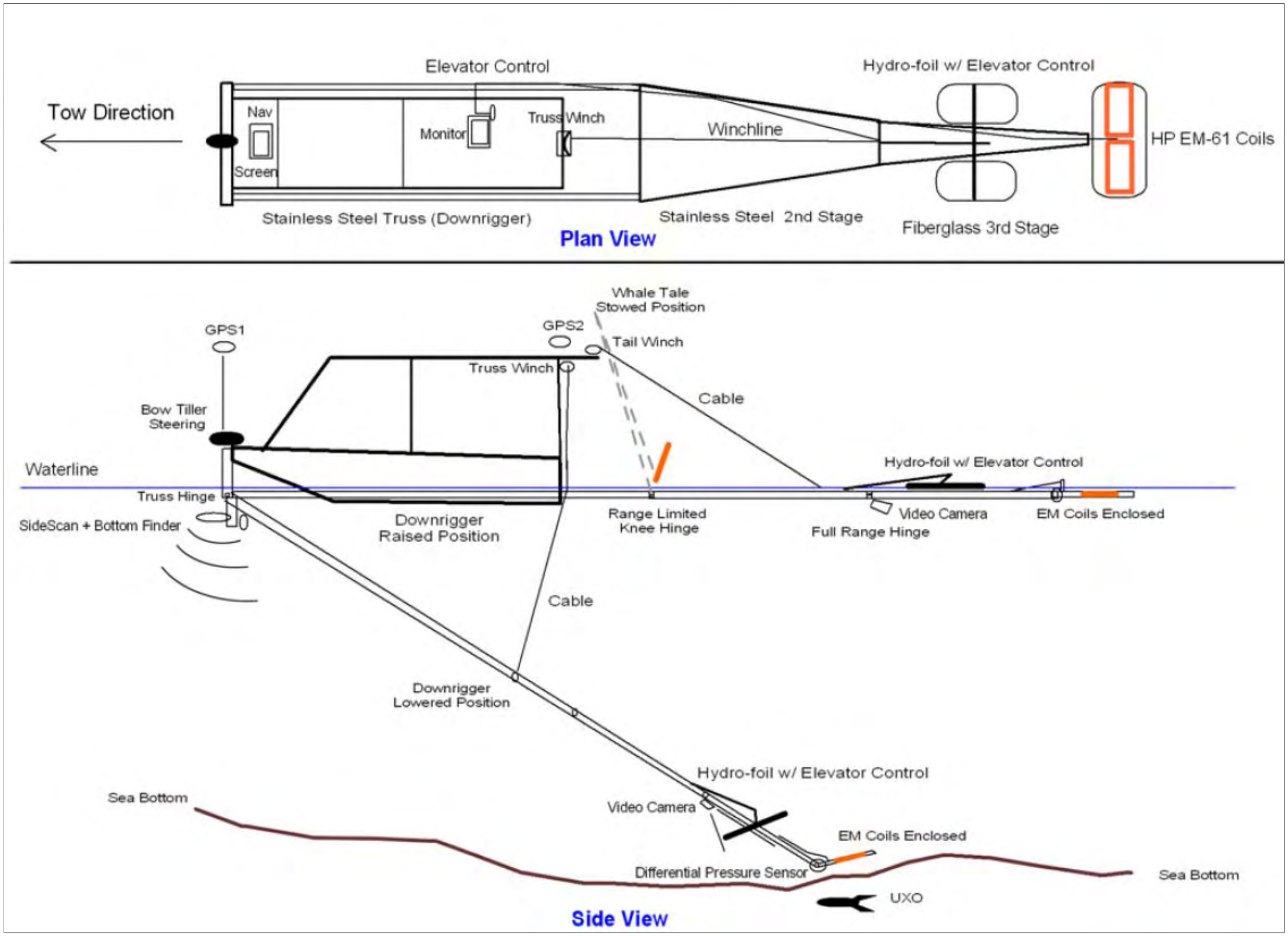


Figure 2-2a: UUTA in parking lot

Figure 2-3b: Collecting geophysical data

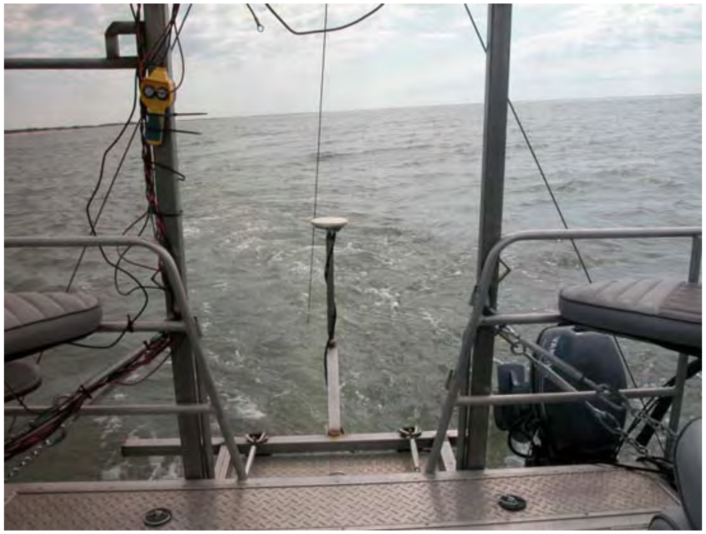


Figure 2-2c: Rear of boat with tail submerged

Figure 2-2d: Deploying the tail

Figure 2-2: Photos of UUTA in Production

2.1.2 Towing System

The towing system consists of the following components:

- A 6.7 m ThunderJet jet boat houses the operators and all system components.
- The sensor platform housing the EM61 coils is towed by a stainless steel and fiberglass twin truss system (downrigger) attached to the boat. A wireless winch controller is used to raise and lower the downrigger. An inclinometer measures the deployment angle of the downrigger. The downrigger winches provide the primary stage of depth control over the towed bar and sensor platform. The winches can also be used to pull the entire UUTA system above the water line to facilitate travel to and from the study area. Depth of the sensor platform is monitored and actively controlled during data collection.
- The hydrofoil (also referred to as an elevator) is an active control surface that produces upward and downward force on the sensor platform as it is being towed through the water. The hydrofoil provides the secondary stage of sensor depth control. The system operator manually controls the depth and angle of the hydrofoil during data collection.
- A calibrated pressure transducer is mounted near the sensor platform. The pressure transducer logs and converts measurements to sensor depth below water surface.
- A tiller controlled by a linear actuator is used at the bow of the survey boat to steer when the downrigger is deployed.
- A bottom-finding sonar is mounted near the bow of the boat. The bottom depth data are used by the system control software to calculate the location of the sensor platform with respect to sea bottom.

During data collection, a technician operating the downrigger and hydrofoil monitors both the sensor platform and the sea bottom on a real-time visual display. The technician is tasked with keeping the sensor platform within close proximity of the bottom. The feedback from this display allows the operator to observe and control the height of the platform and avoid sensor contact with the bottom or other obstacles.

Once deployed, the downrigger tow bar renders the normal steering mechanism of the boat (stern thrusting jet drive) ineffective. To overcome this limitation, a tiller is used at the bow of the survey boat to steer left or right using only the straight line thrust of the jet drive when the downrigger is deployed. The tiller is driven by a linear actuator that is controlled remotely by the boat captain. Based on feedback from the boat's navigation system the captain uses the tiller control to steer the UUTA along data collection grid lines.

2.1.3 Navigation, Positioning and Data Collection

The UUTA uses two Trimble Real Time Kinematic (RTK) GPS receivers mounted on fixed or gimbaled staffs along the centerline of the boat. The bow and stern-mounted GPS receivers provide an accurate system to measure position and heading of the vessel. The downrigger is designed only to provide one degree of freedom (up and down), and is configured to keep the EM61 sensors in line with the GPS receivers and the keel of the boat. Since the exact length of

the downrigger is known, recording the inclination angle of the downrigger and the depth of the hydrofoil (with a pressure transducer) allows the exact distance of the sensor array behind the trailing GPS receiver to be calculated. The exact position of the EM sensors is known to within a few inches using the geometry of the rigid tow structure and the depth sensor.

A Trimble FmX navigation system provides real-time graphical guidance along virtual grid lines that are established over survey areas. The boat captain uses the FmX display to systematically drive the UUTA across the survey area according to the pre-planned survey geometry. The FmX navigation system is integrated with the Trimble RTK GPS receivers. The survey geometry (survey line spacing and boundaries) is designed prior to deployment of the field team using GIS software and uploaded in the FmX navigation system. During data collection the FmX navigation system graphically displayed the current position of the UUTA, virtual grid lines, previously collected survey lines (swath coverage), and data gaps.

During field operations data are collected using a ruggedized PC that is housed in the tow vessel. All measured parameters including the EM61 response are collected and managed by software developed by Geomar, Inc. This includes all data from the positioning sensors (inclinometer, bottom sonar, and pressure transducer), GPS and EM61, and the calculations required for sensor positioning with respect to GPS location and system geometry.

2.2 DEVELOPMENT CHRONOLOGY

The UXO detection capabilities of the UUTA are based on the tested and proven EM61- metal detection system. ESTCP has funded a number of studies of this technology. The EM61-MK2 design and electronics continues to be the instrument of choice for the majority of UXO/MEC DGM surveys performed.

In September 2006, AMEC and 3Dg performed a technology demonstration at the US Army Aberdeen Test Center, Shallow Water Test Site located at Aberdeen Proving Ground, Maryland (DTC Project No. 8-CO-160-UXO-016). The technology demonstration involved testing of an underwater sensor platform at the site, which provided a controlled environment containing varying water depths, multiple types of ordnance and clutter items, as well as navigational and detection challenges. ESTCP was one of several government entities that provided funding and support for the Standardized UXO Technology Demonstration Site Program, where the Shallow Water Test Site was included. As a result of this technology demonstration and the lessons learned therein 3Dg began to conceptualize the design for the UUTA system.

In August 2009, 3Dg began construction of the UUTA system. All components of the UUTA, including the boat, were acquired and assembled by 3Dg without funding from ESTCP. Several minor modifications were made to the UUTA design as a result of the testing performed in advance of the field demonstration at Camp Lejeune (Section 5.2).

2.3 ADVANTAGES AND LIMITATIONS OF THE UUTA TECHNOLOGY

Two challenges of collecting useful underwater UXO detection data are measuring the exact position (both horizontal and vertical) of the EM sensors and controlling the vertical position of the sensor platform. Many tested and deployed UXO mapping technologies employ either a

sensor “fish” or a bottom dragging sensor sled on the end of a flexible tow wire. These systems measure the position of the tow boat and then try to extrapolate the position of the detector based on cable length and GPS heading. In most cases, the position of the fish or sled cannot be accurately known in real-world field conditions (i.e. with water currents, wind, tidal forces and irregular bottom structure). Geo-referencing data with these systems is typically less accurate than is considered acceptable in traditional terrestrial UXO surveys. In addition, both types of systems are hard to control (laterally and vertically) with flexible tow wires that have unlimited range of movement. Bottom draggers often drag along sinusoid tracks (i.e. not directly behind the boat on the boat heading) making gap free coverage time consuming, expensive, and in challenging environments logistically impossible. These limitations are minimized using the UUTA technology.

2.3.1 Advantages

UUTA provides advantages over other available underwater UXO mapping systems and overcomes positioning and sensor control challenges. The UUTA is one of the few marine systems that can measure the X,Y position of the sensors with better than 1-m accuracy. In addition it can accurately measure and control the vertical position (height) of the sensor platform above the ocean/lake bottom. Without these two critical features, other aspects of a marine UXO system are diminished.

Since the UUTA is a non-contact system physical contact and disruption does not occur with the sea/lake bottom. The benefits of such systems include the avoidance of disrupting wildlife habitats, degrading water clarity (sediment pollution), or disturbing contaminated sediments, as well as the minimization of impacts to commercial fishing and potential UXO strikes. Many states have regulations for maintaining water clarity in streams and tributaries, and thus would favor this technology. Bottom dragging systems are also susceptible to creating apparent geophysical anomalies not associated with UXO. Sudden impacts of the sensor platform with bottom obstructions, or the bottom itself, create erroneous anomalies ("false positives") that can mistakenly be interpreted as UXO.

Another advantage of the UUTA system is that it employs the latest modifications to the Geonics EM61 metal detector. Modifications include higher transmitter power and frequency, faster sampling rates, and flexible underwater transmitter and receiver coils. These modifications improve the signal-to-noise ratio of the system, the maximum depth of penetration, the speed of data collection, and the field survivability/ruggedness of the sensors.

The UUTA was designed to integrate with commercially available towing vessels. As such, the UUTA can be easily trailered for transport and rapidly deployed like a regular fishing boat. Other current marine surveying technologies require custom shipping solutions for mobilization and specialized heavy equipment such as cranes for deployment.

2.3.2 Limitations

One limitation of the UUTA system is the range of acceptable water depths for operation. The system was designed to collect data between 1 – 10 m bsl. Because of its rigid design to improve sensor positioning accuracy the UUTA system has limited maneuverability when the tow bar is

deployed. It was designed to perform DGM along large radius turns or straight survey lines. Tight radius turning by the tow boat is limited with the UUTA fully deployed for data collection.

Other system limitations are the result of weather and sea state. It was expected that oceanographic and meteorological conditions would impact the technology demonstration; specifically the total area surveyed and the achieved production rate. This assumption proved correct. Excessively windy, rainy, lightning, strong current, and/or strong tidal conditions negatively affect UUTA production. On several days of the scheduled field demonstration data collection was either severally restricted or eliminated by the environmental conditions. It was determined during the demonstration that the maximum wave height in which data collection could be conducted was 1 m. The towing system, hydrofoil, and tiller were not designed to withstand that level of sea state, and minor repairs to the UUTA were required after work in higher seas was attempted.

3.0 PERFORMANCE OBJECTIVES

The objective of the demonstration was to test and validate the UUTA in shallow water (1 to 10 m bsl) for the accurate detection and location of MEC. The primary emphasis was to demonstrate in dynamic marine conditions, highly accurate horizontal (lateral) and vertical (height above sea floor) position control for an UXO detection array. This survey demonstrated the system performance while providing data that are of benefit to USMC at Camp Lejeune in assessing the MEC contamination in the survey area. The field demonstration included the acquisition of EM data within portions of the designated 101 hectare (ha) (250-acre) survey area and specifically within a zone with measured water depths ranging from 1.5 – 7 m (mean 4.0 m).

The four evaluated performance objectives include positional accuracy, production rate, sensor proximity and probability of detection. **Table 3-1** presents the performance objectives for the field demonstration.

Table 3-1: Performance Objectives

Performance Objective	Metric	Data Required	Success Criteria
Positional Accuracy	Number of items reacquired within 1 m of detected position	• Target list with position coordinates • Validation data for selected targets	95% of all recovered and IVS items reacquired within 1 m of detected position
Production Rate	Number of acres of data collection per day	• Distance platform has traveled and width of transect	5 acres/day (2.02 ha/day)
Probability of Detection	Number of IVS items found	• Number of total items within surveyed area • Number of items found	95% of all items detected
Sensor Proximity	Number of EM sensor readings recorded within 1 m of the sea floor	• Sensor array depth • Bottom depth	90% of all EM readings recorded with the sensor array height ≤ 1 m above the sea floor

3.1 OBJECTIVE: POSITIONAL ACCURACY

The objective of this technology for the detection of MEC is to accurately record the horizontal (X,Y) georeferenced position of mapped EM anomalies.

3.1.1 Metric

The reacquired targets are located within 1 m of the geophysically mapped target location.

3.1.2 Data Requirements

The positional accuracy of the technology was measured through validation of 63 detected EM targets. A prioritized list of detected EM targets was generated from the DGM survey data. The target list included locations of 10 Instrument Verification Strip (IVS) seed items that were

mapped (i.e. data were acquired within 0.5 m of the known locations of the seed items). The GPS positions of the 63 validated targets were directly measured by the reacquisition team.

3.1.3 Success Criteria

The positional accuracy objective would be deemed a success if the measured GPS positions of more than 95% of the validated targets and IVS items are located within 1 m of the geophysically mapped positions.

3.2 OBJECTIVE: PRODUCTION RATE

The objective of this technology for the detection of MEC is to rapidly collect data over large survey areas.

3.2.1 Metric

The calculated production rate of the system (total area surveyed divided by the data collection time measured in days) during the demonstration was the metric used.

3.2.2 Data Requirements

The production rate of the system was measured by calculating the total area surveyed during the demonstration (96.9 acres) and recording the amount of time spent during data collection (12 days). The total area surveyed was calculated by recording the distance the sensor platform has traveled during the survey (based on GPS positions of the collected data) and the measured 2.0 m width of the sensor platform.

3.2.3 Success Criteria

The production rate objective would be deemed a success if the calculated production rate of the system exceeds 5 acres per day during the demonstration.

3.3 OBJECTIVE: PROBABILITY OF DETECTION

The objective of this technology for the detection of MEC is to record EM targets over a high percentage of seeded target items. The probability of detection (Pd) at a specified confidence level (CL) in a standard terrestrial UXO environment requires an emplacement plan that is designed to allow for Pd and CL determination based upon a population of munitions of interest, expected depths below ground surface versus the specific munitions and the specified depths for the site. Blind seeding was not included in this demonstration as it was logistically difficult and technically improbable to seed items in the seafloor in water depths greater than 1.5 m. Verification and survey of seed locations and potential movement as a result of wave action and tidal forces was not practical. The ability to demonstrate realistic Pd and CL for an expected population of seed items was therefore not planned or accomplished.

To address the limitations for Pd determination and provide a metric for detection response and positional accuracy, a chained IVS was installed with the intent to provide a viable, cost effective tool to test the UUTA in the shallow water environment. The chained IVS was conceptualized

as a marine analogy to an IVS that is commonly used in terrestrial UXO detection surveys. The chained IVS seed items were used to calculate the probability of detection for the system.

3.3.1 Metric

The total number of EM targets identified over the known location of the seeded targets on the chained IVS was recorded.

3.3.2 Data Requirements

The Pd of the technology was measured through validation of the detected EM anomalies from seeded targets on the chained IVS. DGM data were collected over the areas that encompassed the seeded items on the IVS. After collecting the DGM data, the data were processed and analyzed as described in Section 6.0 of this document. A list of detected EM targets was generated from the processed and gridded DGM survey data. The GPS positions of the IVS seed items were directly measured during the validation phase of the work (see Section 5.6).

3.3.3 Success Criteria

The objective would be considered a success if more than 95% of the validated IVS seed items were detected during the DGM

3.4 OBJECTIVE: SENSOR PROXIMITY

The objective of this technology for the detection of MEC is to control and record the vertical position (height above sea floor) of the sensor platform.

3.4.1 Metric

Vertical position of every unique EM sensor reading was collected during the demonstration.

3.4.2 Data Requirements

The sensor proximity of the system was measured by recording bottom depth with sonar transducer and sensor platform depth with pressure transducer during the DGM. The height of the sensor platform above the sea floor was calculated by subtracting the measured platform depth from the measured bottom depth at every one of the 4,382,130 unique EM sample positions.

3.4.3 Success Criteria

The sensor proximity objective would be deemed a success if the calculated sensor height above sea floor is less than or equal to 1 m for more than 90% of the EM sensor readings.

4.0 SITE DESCRIPTION

The geophysical demonstration site was located at Camp Lejeune, North Carolina. The technology demonstration included a DGM survey for UXO/MEC detection within a portion of an approximate 250 acre shallow water area adjacent to Browns Island along the near shore zone within the Camp Lejeune boundary (**Figure 4-1**). The site extends from the low water mark to a depth of approximately 7.5 m and parallels the shoreline beach. The following sections provide more site details.

4.1 SITE SELECTION

The site was selected by USMC Camp Lejeune because of great interest in determining the presence of UXO in an ocean area that may be encountered by the public. The site is along the Atlantic Ocean coast where the public can easily access it even though extensive warning signs in place indicate the potential danger from UXO on the beach and in the ocean. The use of marine based DGM surveys and monitoring for MEC/UXO detection is needed where access to the public is somewhat uncontrolled. This location at Camp Lejeune provides a good site to demonstrate a new design for MEC/UXO site characterization and monitoring.

4.2 SITE HISTORY

Established in May 1941, Marine Corps Base (MCB) Camp Lejeune, North Carolina provides specialized training to prepare troops for amphibious and land combat operations. Today MCB Camp Lejeune occupies 153,000 acres (61948 ha) with a diverse array of ecosystems composed of wild lands, urban areas, and surface water resources. Over 100,000 acres (40,469 ha) of land are in forests and other wild lands. Water resources include approximately 11 miles (17.7 kilometers [km]) of beach on the Atlantic Ocean and 26,000 acres (10526 hectares) of estuaries containing the New River, Intracoastal Waterway and associated streams and marshes. In addition to 450 miles (724 km) of roads and 50 miles (80.5 km) of railroads, on-base mission support facilities include a 15 million gallons (57,000,000 liters) a day Advanced Wastewater Treatment plant, five water treatment plants, a Subtitle D municipal solid waste landfill, and 6,800 buildings and facilities supporting 144,000 Marines, Sailors, and their families. The Base houses six major Marine Corps commands and two Navy commands.

4.3 SITE GEOLOGY

Camp Lejeune is located within the North Carolina Coastal Plain belt that covers a large portion of the state. The geology of the study area consists primarily of marine sediments with dominant sand, silt and clay. The wave and tidal action in the study area alters the beach and near shore sediments on a regular basis. The Coastal Plain Region of North Carolina consists of a wedge of Cretaceous and Tertiary sedimentary strata thickening toward the coast as well as dipping toward the southeast. Outcropping strata, away from the study area are younger near the coast. The sedimentary rocks of the Coastal Plain partly consist of sediment eroded from the Piedmont and Valley and Ridge and partly of limestone generated by marine organisms and processes. The North Carolina Coastal Plain belt covers a large portion of the state. The most common sediment types are sand and clay, although a significant amount of limestone occurs in the southern portion.

Figure 4-1: Shallow Water Survey Area

4.4 MUNITIONS CONTAMINATION

The coastal beach area was a former bombing and artillery range at Camp Lejeune from the 1940s through the 1980s, located within impact area BT-3/N-1 between Onslow Beach and Hammocks Beach State Park,. UXO ranging from 40 millimeter (mm) grenades to 2000-pound (lb) bombs, may be located throughout the beach and coastal region. The Navy and Marines occasionally sweep the area and remove any items discovered on the beach. Local fishermen are also known to accidentally retrieve potential UXO in their fishing nets. These areas, are sometimes considered by water craft as a potential beaching area, and may be used by local boaters and fishermen despite warning signs, creating a safety hazard.

A UXO sweep of the beach area in January and February of 2009 discovered items including Mk23 (3lb) Practice Bomb, 100 lb GP Bomb, Mk 81 Bomb, Mk 82 Bomb, 5 inch Naval Round HE, 106m HEAT, 155mm HE, 90mmHE, 2.75 inch Rocket HE, 500 lb GP Bomb and 250 lb GP Bomb. Photos in **Figure 4-2** show examples of what has been previously found on the beach adjacent to the site, including metallic non munitions debris.

MK-82

750lbs bomb

MK-82

250lbs bomb

Figure 4-2: Previously Discovered MEC at the Site

5.0 TEST DESIGN

The following sections detail the field tests that were conducted to address the performance objectives (Section 3.0) of the UUTA technology demonstration.

5.1 CONCEPTUAL EXPERIMENTAL DESIGN

The objective of the demonstration was to test and validate the UUTA performance for the accurate detection and location of MEC. The primary emphasis was to demonstrate that in dynamic marine conditions, highly accurate horizontal and vertical position control for UXO detection mapping could be accomplished. For the demonstration, commercially available geophysical and GPS instruments were integrated on a newly designed underwater towed array platform that provides accurate position control and may address potential future regulations that restrict the use of bottom dragging systems. The technology demonstration was conducted in three phases: site visit; instrument testing; and, field test / validation.

The initial site visit was conducted in November 2009. An objective of the first site visit was to observe the local oceanographic and meteorological conditions so that negative impacts to the field test could be planned for and minimized. It was also a priority during the site visit to select equipment storage and maintenance facilities, determine the optimum survey time window, evaluate safety aspects, and incorporate other concerns of USMC Camp Lejeune personnel. Based on the site visit, the technology demonstration was scheduled to begin in May 2010 to maximize the potential for high production rates while maintaining safety.

To realize the demonstration goals, the prototype UUTA system required in-field testing and calibration. Prior to deployment of the field test at Camp Lejeune, extensive instrument testing was implemented so that the various navigational and positional sensors and quality control systems of the UUTA could be precisely calibrated and properly integrated with the modified EM61 metal detection system. Additionally, instrument testing was performed to determine the operational limits of the UUTA design (boat speed, maximum/minimum deployment depth, etc.), and the optimum data collection parameters prior to the field test at Camp Lejeune. Implementation of this task helped to minimize production losses during the technology demonstration by anticipating potential equipment failure and/or system integration incompatibilities. The instrument testing was conducted in suitable lakes and rivers near the 3Dg offices located in Chaska, Minnesota (MN), and in Lake Clinton, Kansas (KS) during the time period of November 2009 – May 2010.

In addition the system was field tested at Camp Lejeune one week prior to the demonstration. The instrument testing results are discussed in Section 5.2 below. The Camp Lejeune field test was performed at a shallow water area located near Browns Island within the site (Figure 4-1). The duration of the field test was approximately 7.5 weeks (May 17 to July 6, 2010). The field test data collection parameters and procedures are detailed in Sections 5.6 and 5.7.

5.2 SYSTEM TESTING

The design field testing included seven quantitative or qualitative evaluations of the UUTA system. The design testing evaluated the following performance categories: vessel velocity; data collection depth; pressure sensor calibration; water depth transducer calibration; sensor array depth and roll control; system latency and positional accuracy; and static response.

5.2.1 Vessel Velocity

Vessel velocity testing was performed on Clinton Lake, KS during March of 2010 because the waters in Minnesota were still covered with ice. The purpose of the vessel velocity testing was to determine the maximum speed that the boat could travel without the UUTA deployed (i.e. travel mode), and the maximum and minimum travel speed during full deployment with the complete towing structure in the water. A minimum speed was required during UUTA deployment to keep the sensor platform in a stable, horizontal orientation within the water column. **Table 5-1** summarizes the results of the testing.

Table 5-1: Vessel Velocity Testing Results

Vessel Velocity – Travel Mode		Vessel Velocity – UUTA Deployed	
Min	Max	Min	Max
0 mph[a] (0 kph[b])	8.1 mph (13.04 kph)	1.5 mph (2.41 kph)	6 mph (9.66 kph)

Notes: [a] miles per hour
[b] kilometers per hour

5.2.2 Data Collection Depth

Data collection depth testing was performed on Clinton Lake, KS and Lake Bavaria, MN. The purpose of the depth testing was to determine the water depth that the sensor platform could be maintained at various boat speeds and downrigger angles. As a result of this testing several minor design modifications were made to the UUTA system. Modifications included: shape and pivot of the hydrofoil; shape, placement, and structural design of the front rudder; sensor platform structural design; reinforcement of the downrigger/truss system; and the change from a single winch to a dual winch system for control of the downrigger.

Table 5-2 summarizes the data collection depth results using the final UUTA design. The table provides the measured sensor platform depth as a function of boat speed, downrigger angle, and hydrofoil angle at maximum lift, neutral position, and maximum downforce. The bold type table entries indicate boat speed and hydrofoil combinations at which the intended downrigger angles could not be maintained.

5.2.3 Pressure Sensor Calibration

Pressure sensor calibration testing was performed on Clinton Lake, KS and Lake Bavaria, MN. The purpose of the testing was to verify that the output of the pressure sensor was operating

Table 5-2: Data Collection Depth Testing Results

	SENSOR PLATFORM DEPTH BELOW WATER SURFACE, ft (m)											
	Boat Speed – Hydrofoil Position											
	2 mph			3 mph			4 mph			5 mph		
Down-rigger Angle (deg)	**Max Down**	**Neutral**	**Max Lift**	**Max Down**	**Neutral**	**Max Lift**	**Max Down**	**Neutral**	**Max Lift**	**Max Down**	**Neutral**	**Max Lift**
5	14.1 (4.3)	7.2 (2.2)	1.3 (0.4)	13.6 (4.1)	6.0 (1.8)	0.0 (0.0)	12.1 (3.7)	5.4 (1.6)	0.0 (0.0)	11.6 (3.5)	4.2 (1.28	0.0 (0.0)
10	17.1 (5.1)	9.9 (3.0)	5.2 (1.6)	16.5 (5.0)	8.9 (2,7)	3.1 (0.9)	14.9 (4.5)	8.0 (2.4)	0.5 (0.15)	13.9 (4.23)	7.3 (2.2)	0.0 (0.0)
15	20.3 (6.2)	14.1 (4.3)	7.4 (2.3)	19.4 (5.9)	12.8 (3.9)	6.0 (1.8)	18.1 (5.5)	11.9 (3.6)	5.4 (1.6)	16.9 (5.2)	10.3 (3.1)	3.6 (1.1)
20	22.8 (6.9)	16.5 (5.0)	10.0 (3.0)	21.5 (6.4)	15.2 (4.6)	7.6 (2.3)	20.5 (6.6)	14.3 (4.4)	6.4 (1.9)	19.5 (5.9)	12.3 (3.7)	5.0 (1.5)
25	25.3 (7.7)	19.3 (5.9)	12.8 (3.9)	24.4 (7.4)	17.8 (5.4)	10.4 (3.2)	23.1 (7.0)	16.0 (4.9)	9.2 (2.8)	20.9 (6.4)	14.2 (4.3)	6.6 (2.0)
30	27.7 (8.4)	22.7 (6.9)	17.1 (5.2)	27.1 (8.3)	20.8 (6.3)	12.9 (3.9)	25.7 (7.8)	18.0 (5.5)	11.1 (3.4)	23.4 (7.1)	16.4 (5.0)	***8.6 (2.6)***
35	30.8 (9.4)	25.1 (7,6)	18.8 (5.7)	29.5 (9.0)	22.7 (6.9)	14.8 (4.5)	28.3 (8.6)	20.0 (6.1)	12.5 (3.8)	25.6 (7.8)	***17.4 (5.3)***	***8.1 (2.5)***
40	32.9 (10.0)	27.7 (8.3)	20.0 (6.1)	32.0 (9.8)	25.5 (7.8)	15.9 (4.8)	29.9 (9.1)	21.6 (6.6)	***13.4 (4.1)***	***28.0 (8.5)***	***18.0 (5.5)***	***8.7 (2.6)***
45	35.4 (10.8)	30.4 (9.3)	21.4 (6.5)	33.8 (10.3)	27.0 (8.2)	18.0 (5.5)	32.3 (9.8)	***22.4 (6.8)***	***11.5 (3.5)***	***29.0 (8.8)***	***17.4 (5.3)***	***8.1 (2.5)***

BOLD Italic entries indicate boat speed – hydrofoil combinations at which the intended downrigger angles could not be maintained.

within manufacturer specifications. The pressure sensor is attached to the EM61 coil complex at the end of the UUTA downrigger. It provides data critical to calculating the sensor height above sea floor and the position (i.e. offset behind the boat) of the sensor platform. The pressure sensor measurements were verified on several occasions at various water depths using a tape measure. The sensor was proven to operate within the specified tolerances (±0.021 m) for the depth range 0 – 20.4 m though tested for this demonstration only to 10.8 m.

5.2.4 Water Depth Transducer Calibration

Water depth transducer calibration testing was performed on Clinton Lake, KS, Lake Bavaria, MN, and at Camp Lejeune. The purpose of the testing was to verify the accurate output of the depth transducer and to select appropriate operating parameters for the depth ranges and bottom conditions to be encountered during the field demonstration. The depth transducer, which is attached to the bow of the boat, provides data critical to calculating the sensor height above sea floor and for monitoring topographic changes. The depth transducer, which has a manufacturer specified maximum detection depth of 457.2 m), was tested on several occasions at various bottom depths in the range of interest (1 – 10 m) using tape measures. Gain, transducer frequency, and filter settings were established to best image the bottom conditions at Camp Lejeune.

5.2.5 Sensor Array Depth & Roll Control Testing

Sensor array depth and roll control testing was performed on Clinton Lake, KS and Lake Bavaria, MN. The purpose of the depth and roll testing was to determine if the height of the sensor platform in the water column could be maintained with the boat traveling at data collection speeds from 3 to 5 mph (4.8 to 8.05 kph), and if the platform was flying level (i.e. a zero degree roll angle). This testing was conducted several times. As a result, several minor design modifications were made to the UUTA system. Specifically the hydrofoil control surface and the sensor platform were modified so that more precise control of the system could be achieved. An underwater video camera and a bubble level were used to monitor the sensor platform orientation during the testing. The testing results showed that that the depth of the sensor platform remains constant and flies level when the hydrofoil remains in fixed orientation.

5.2.6 System Latency & On-land Positional Accuracy

System latency and positional accuracy testing was performed on Lake Bavaria, MN and at the 3Dg offices. The purpose of the system latency testing was to calculate the time correction applied to the DGM data to correctly synchronize the EM and GPS positional data. System latency is a function of the combined timing inaccuracies from the GPS receivers, the EM61 electronics, and the data logging computer. To calculate the latency of the UUTA system, the positional accuracy of the entire system also required testing. The test consisted of dry land and in water data collection. At the 3Dg offices a test object (10 lb dumbbell weight) was placed on a paved road and its position recorded with an RTK GPS. The UUTA was then fully deployed with the tow boat on a trailer attached to a cargo van. Technicians held the extended sensor platform at a fixed height to simulate water surface as if the system had been deployed in a lake or ocean. Data were collected over the test object by driving the trailer mounted UUTA along the road at walking speeds (approximately 3 mph). The test was performed twice, with data

being collected along straight lines with opposite headings. A similar test was then conducted in Lake Bavaria with a test object placed on the lake bottom at a water depth of 16.4 ft (5 m). Again, the UUTA was towed over the test object along two lines with opposing headings. Unlike the terrestrial test that mimicked data collection at the water surface, the in water test required full deployment of the UUTA system and accurate function of all positional sensors to correctly calculate the test object position. The terrestrial and water datasets were analyzed using Geosoft UX-Process software. **Figure 5-1** shows a plot of EM response over a test object in Lake Bavaria before and after system latency correction was applied. The tests verified that the positional accuracy of the UUTA exceeded the success metric of 1 m established for the demonstration. The latency correction was calculated at 0.2 seconds. Further comprehensive testing of positional accuracy occurred with the IVS and UUTA in the shallow water environment as discussed later in Section 5.2.

5.2.7 Static Response

Static response testing was performed at the 3Dg offices. The purpose of the static testing was to test the overall response of the new EM61 modifications as well as to determine the construction materials for the chained IVS. A test jig was constructed for the EM61 coil complex. During the test, data were recorded for the background (i.e. noise) as well as the EM response of several UXO surrogate objects and potential IVS construction items at 5 different coil heights (1, 2, 3, 4, and 5 ft (.30, .61, .91, 1.2, 1.5 m) above ground). The test objects consisted of the following: small, medium, and large industry standard objects (ISO); 6, 8, and 12-in diameter, 1/4-inch thick (.15 m, .20 m and .30 m, 6.35 mm thick) steel discs; 3/16-inch (7,62 cm) diameter stainless and galvanized steel cable. The asymmetric objects were tested in two different orientations; inline and perpendicular to the longitudinal axis of the EM61 coils. A total of 14 static tests were collected at each coil height. For each object placed in the test jig, data were recorded for a total of 30 seconds. The results of the static response testing are summarized in **Table 5-3**. The data table lists measured EM amplitude in mV using time gate 3 of the EM61. Values in bold italics indicate amplitudes measured at or below the root mean square (RMS) background noise floor. Measured background RMS noise values varied from 0.6 – 1.1 mV.

The results of the testing suggest that the modified EM61 system produces an EM response that is an order of magnitude more sensitive than the standard EM-61 MK2 (as reported by the Naval Research Lab – March 12, 2009 study). The RMS noise values, however, are within the same order of magnitude for both systems. Neither of the proposed construction items for the chained IVS (stainless steel or galvanized steel cable) is detectable by the system. In addition, the steel disks that 3Dg preferred to use for the seed items on the IVS compared favorably (in terms of EM response) to the standardized UXO surrogate items.

5.3 SITE PREPARATION

The USMC provided all necessary permits for work to be conducted in the survey area. The primary preparatory work required for the site was the fabrication and deployment of the chained IVS. The intent of the chained IVS was to provide a viable, cost effective tool to test the EM detection response and positional accuracy of the UUTA system in a shallow water environment. The chained IVS is analogous to a standard IVS that is commonly used in terrestrial UXO detection surveys.

Figure 5-1: System Latency Correction

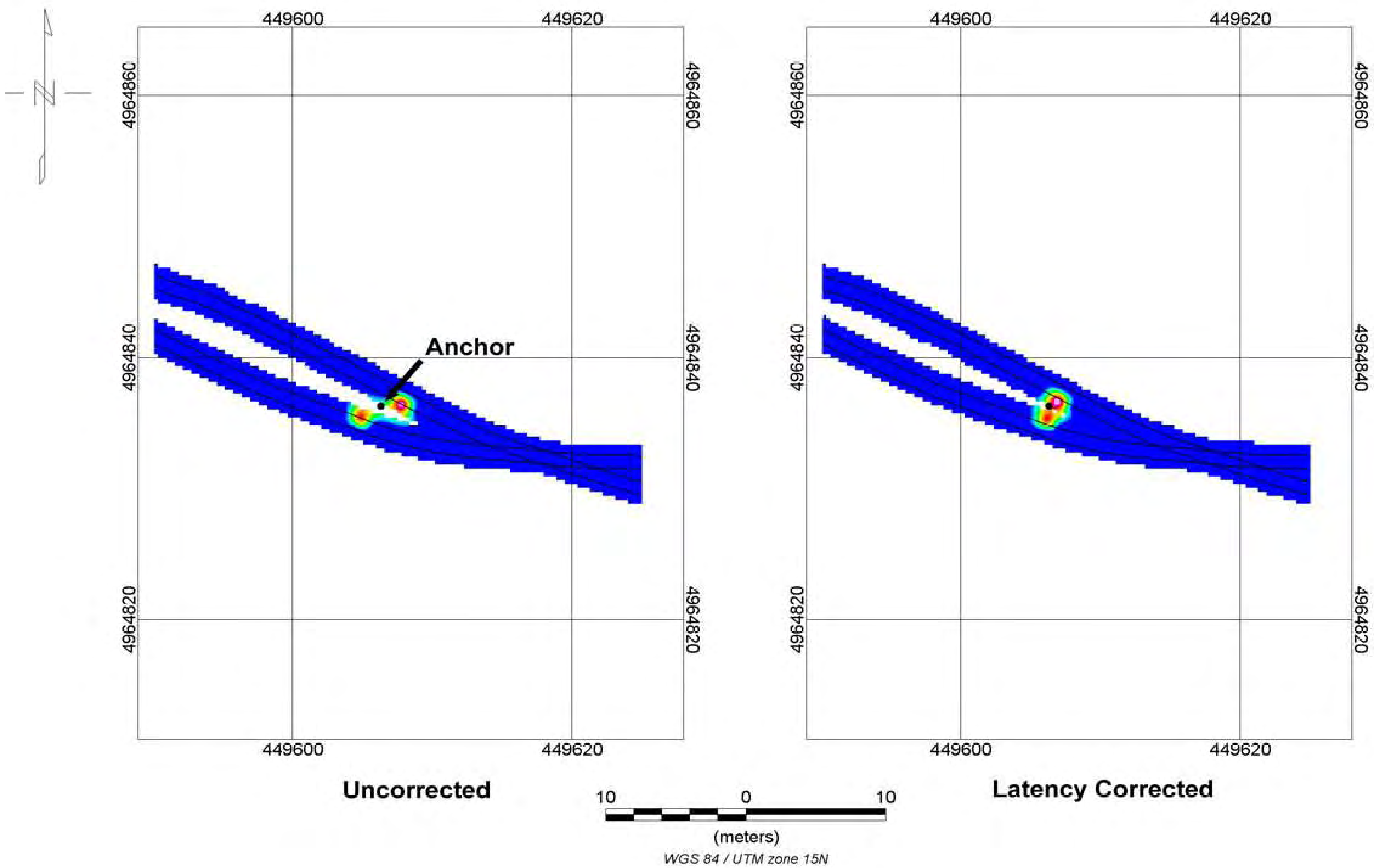


Table 5-3: Static Response Results

	EM Response (millivolts)													
Coil Ht ft(m)	**Back-ground**	**SC inline**	**SC perp**	**GC inline**	**GC perp**	**1" inline**	**1" perp**	**2" inline**	**2" perp**	**4" inline**	**4" perp**	**6" disk**	**8" disk**	**12" disk**
1 (.30)	1.1	*0.1*	*-0.2*	*1.1*	*0.2*	532.9	528.4	6134.1	5980.5	26955.7	27179.3	2277.3	6792.3	20787.9
2 (.60)	0.7	*0.6*	*-0.1*	*0.4*	*0.5*	68.9	69.9	732.3	739.5	5934.1	6083.8	281.1	841.8	2852.8
3 (.91)	0.8	*0.1*	*-0.1*	*-0.4*	*0.1*	8.9	8.2	84.0	85.8	630.3	630.6	35.1	102.8	340.6
4 (1.21)	0.6	*0.6*	*-0.8*	*0.1*	*-0.3*	2.5	2.1	24.5	24.4	184.7	182.2	9.9	30.7	103.0
5 (1.52)	0.7	*0.4*	*0.1*	*0.3*	*-0.1*	*0.7*	*0.5*	7.7	6.9	64.4	61.8	5.4	12.9	38.8

Red italic numbers indicate values below the RMS background noise level (i.e. non-detectable).

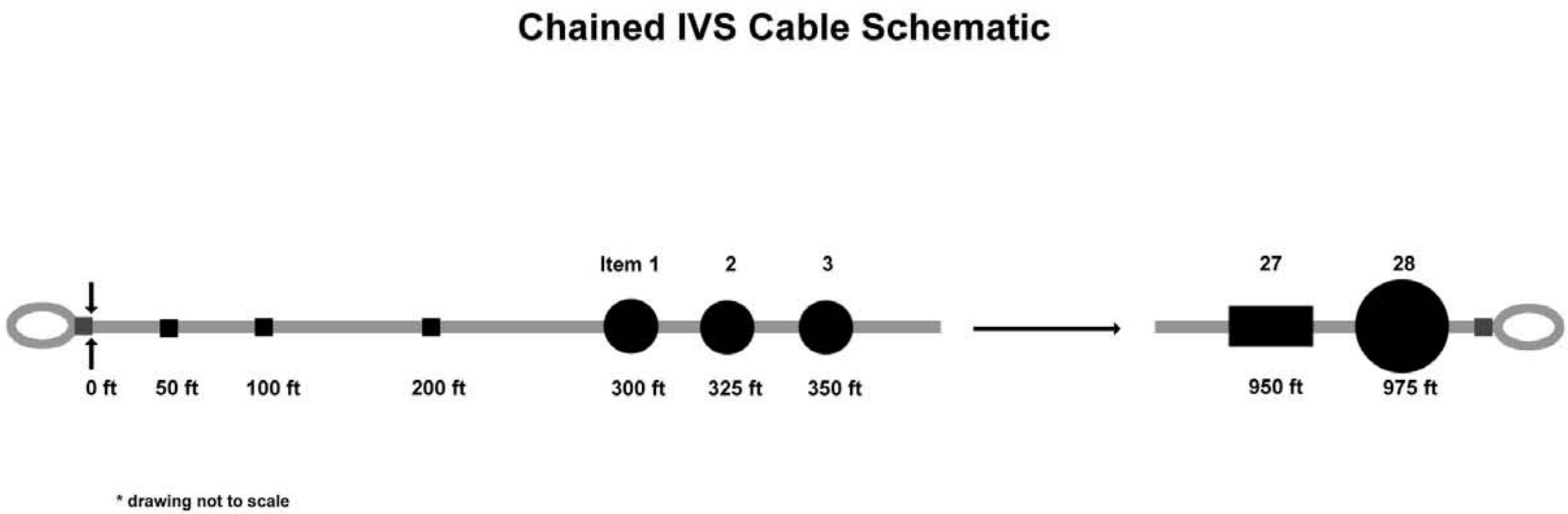
SC inline	3/16" dia. stainless steel cable; inline to direction of travel
SC perp	3/16" dia. stainless steel cable; perpendicular to direction of travel
GC inline	3/16" dia. galvanized steel cable; inline to direction of travel
GC perp	3/16" dia. galvanized steel cable; perpendicular to direction of travel
1" inline	1" dia., 4" length steel pipe (small surrogate); inline to direction of travel
1" perp	1" dia., 4" length steel pipe (small surrogate); perpendicular to direction of travel
2" inline	2" dia., 8" length steel pipe (medium surrogate); inline to direction of travel
2" perp	2" dia., 8" length steel pipe (medium surrogate); perpendicular to direction of travel
4" inline	4" dia., 12" length steel pipe (large surrogate); inline to direction of travel
4" perp	4" dia., 12" length steel pipe (large surrogate); perpendicular to direction of travel
6" disk	6" dia., 1/4" thick steel disc
8" disk	8" dia., 1/4" thick steel disc
12" disk	12" dia., 1/4" thick steel disc

The chained IVS consisted of 1000-ft (305 m) of 3/16-in. (4.8 mm) stainless steel cable attached at one end by a heavy-duty spade-type marine boat anchor, and at the other end by a 5-ft (1.5 m) steel winch anchor point. The IVS employed a modification of the geophysical system verification (GSV) concept with standard seed items. As discussed in Section 5.1.7 both ISO and ISO surrogates were used in the creation of the IVS. Steel discs were preferred as the primary seed item because of the logistics of deploying the IVS, and the belief that the flattened discs would scour into the sea bottom and remain stationary throughout the demonstration. Twenty eight (28) seed items were affixed to the steel cable at 25-ft (7.6 m) intervals beginning at the 300 ft (91.4 m) mark and continuing to the end of the cable. **Figure 5-2** shows a schematic drawing of the chained IVS cable.

IVS deployment was initially scheduled for May 21, 2010 but the demonstration was delayed while waiting for safe working conditions and appropriate authorization to work on the beach. Successful deployment was achieved on May 31, 2010. The IVS was deployed in the western end of the survey area, approximately perpendicular to the data collection grid lines, to provide control points to validate the metal detection mapping results. The seaward (anchor) end of the chained IVS was placed first, and then a boat and dive team worked together to lay the cable and seed items along the sea bottom. Once the surf zone was encountered, a 2-person dive crew dragged the free end of the IVS to shore and constructed the winch point. A winch was used to place the steel cable under tensile load until the entire IVS assembly was pulled taught into a straight line. GPS points were then acquired at the ends of the IVS wire to record its general position. **Figure 5-3** shows the surveyed position of the chained IVS on a photograph of the site, and a photograph taken during IVS deployment.

Visual checking of the positional stability of the chained IVS at the beginning and end of each day of data collection had been planned, but field conditions dictated that the field team deduce the stability of IVS as described below. Prior to arriving at the site each day, it was reasoned that if the tension on the winch end of the IVS remained unchanged then it could be assumed that the position of the IVS seed items also remained unchanged. However, the spring tension gauge attached to the winch could not be viewed from the boat because the acquisition team could not maneuver close enough to the shore as a result of the high surf zone. The dangers posed by the surf also prevented the survey team from landing on the island beach to manually check the gauge. However, ancillary evidence suggested that the IVS did not move during the demonstration. Approximately 150 ft (45.7 m) of IVS was visible from the winch point to its entrance into the ocean. The survey team observed that the orientation of the cable did not change during data acquisition. In addition several of the IVS seed items were identified at their known positions as EM detection targets during the DGM. Finally when the OER dive team located and removed the seaward IVS anchor at the conclusion of data collection, the anchor was located at its originally recorded position and the OER team reported that the cable was still under tension.

Figure 5-2: Schematic Drawing of the Chained IVS Cable



Item	No.	Position (ft)
8" disc	1 – 20	300 – 775
1" pipe	21 – 22	800 – 825
6" disc	23 – 24	850 – 875
2" pipe	25 – 26	900 – 925
4" pipe	27	950
12" disc	28	975

Figure 5-3: IVS Location Map

5.4 SYSTEM SPECIFICATION

The components and specifications of the UUTA sensor platform, positioning and data acquisition systems are summarized in **Tables 5-4 and 5-5**.

Table 5-4: UUTA Primary Systems Components

Component / Function	Instrument / Equipment
TDEM Metal Detection Sensor Array	Geonics, Ltd. EM61-Flex4
Sensor Array Positioning	Trimble 5700 RTK DGPS
Sensor Array Navigation & Guidance	Trimble AgGPS FmX Navigation System
Sensor Array Depth Transducer	Campbell Scientific, Inc. CS455 Vented Pressure Transducer
Bottom Depth Transducer	Hummingbird 997c SI combo Depth/Side Imaging Sonar
Data Acquisition System	Panasonic Toughbook PC with Proprietary Data Acquisition Software

Table 5-5: TDEM Sensor Array Specifications

Parameter	Value
Instrument	Geonics EM61-Flex3
Power Mode	High (24 volt)
EM Sensors	2
Coil Type	Flexible, submersible
Receiver (Rx) Coil Geometry	2 per sensor, symmetrical, inline ("Figure 8")
Rx Coil Dimensions	1.0 x 0.2 meter
Transmitter (Tx) Coil Dimensions	2.0 x 0.5 meter
TDEM Recording Window	3rd time gate
Sampling Interval (per sensor)	18 samples/sec

5.5 CALIBRATION ACTIVITIES

To establish confidence in the geophysical mapping, data reliability tests for the UUTA system were conducted in a systematic manner throughout the duration of the technology demonstration.

Quality Control (QC) consisted of daily instrument tests and the collection of data over the chained IVS described in Section 5.3.

Daily tests consisted of a static EM sensor test and a GPS location test performed before underwater data acquisition began. At the onset of the demonstration a launch point (Freeman Creek landing) was established on base near the survey area where the data acquisition team and the safety boat / dive team assembled each morning (**Figure 5-4**). A position with no subsurface metal was established at the landing and designated as the calibration point for the duration of the field test. The boat and UUTA system remained on the trailer during the daily QC tests. A test jig for the EM system was designed by 3Dg prior to mobilization to the test site. The test jig consisted of two Small ISOs (munitions surrogates) attached to the UUTA sensor platform in a fixed orientation. With the test jig in place, sensor readings were collected daily in a stationary position over the calibration point to ensure a stable and repeatable EM response was exhibited. A repeatable response was defined as an EM reading within 10% of the initial static test result. Static test results are shown graphically in Appendix B.

A licensed surveyor from Lanier Surveying Co. (Cedar Point, NC), was contracted during project startup to establish a GPS base station hub at Freeman Creek landing. 3Dg occupied this location with a GPS base station during the entire field demonstration. Two GPS test points were established at the landing near the bow and stern of the boat. The test points were positioned so as to be accessible with the trailer mounted boat and UUTA in the same position as during the EM response test.

During the daily GPS location tests, the position of the GPS test points were measured by the RTK GPS receivers from the UUTA system to ensure that an accurate and repeatable GPS location was exhibited. A repeatable response was defined as a GPS reading within 5 centimeters (cm) of the initial calibration point position. A summary of GPS test results are provided in Appendix C.

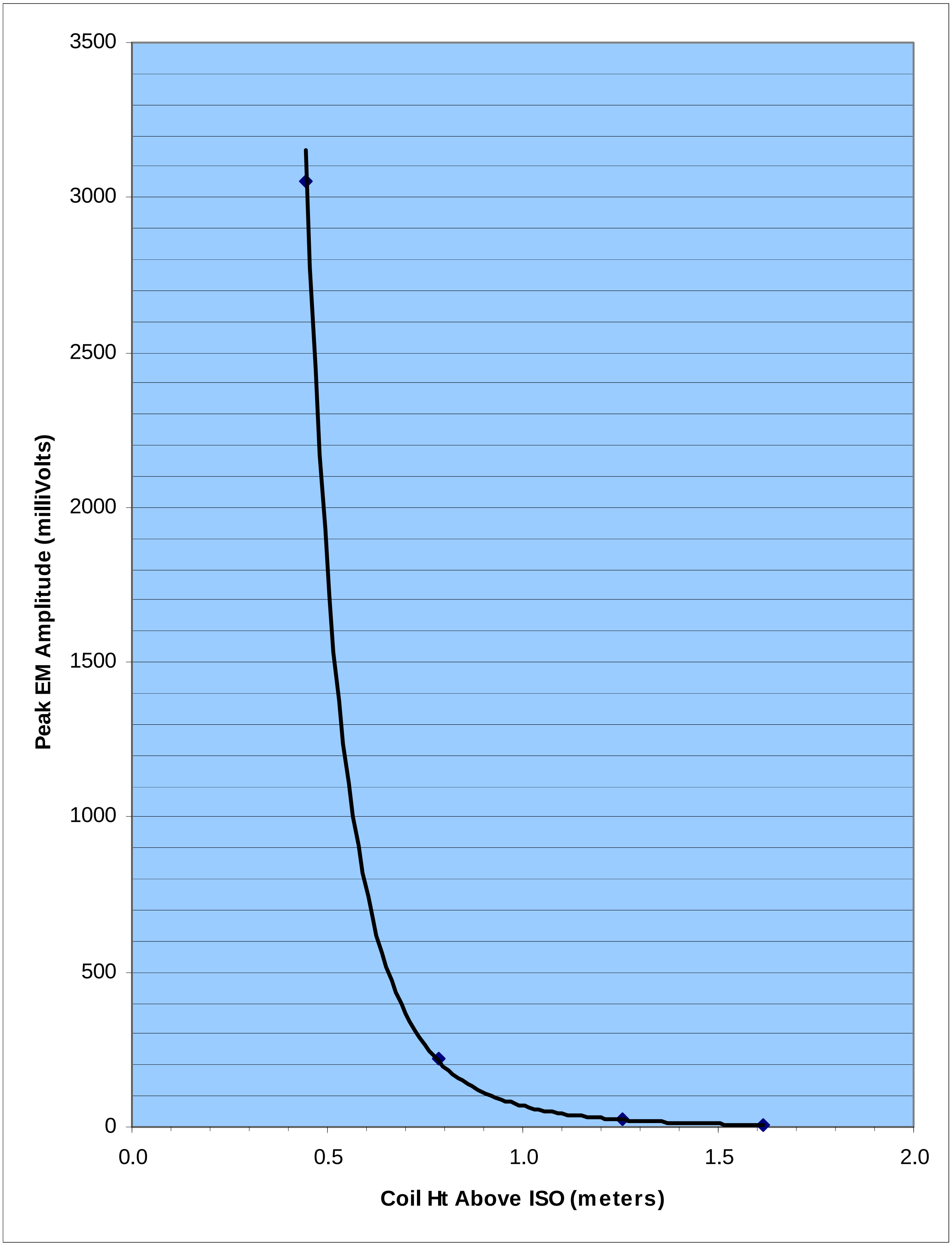
Prior to the beginning of data processing, a target calibration test was conducted at the site to determine the EM anomaly selection criteria to be used during data processing. Based on a historical review of the site usage and suspected MEC in the survey area the Large ISO munitions surrogate was selected to perform the target calibration test. While in a fixed and stationary position at the survey calibration point the EM response of the Large ISO was measured. During the test the static response (peak amplitude) of the Large ISO was measured at 4 different distances, ranging from 17 – 64 inches (43 cm-1.43 m), below the EM sensors. **Figure 5-5** shows the results of the target calibration test. Based on the results of the calibration test a target anomaly threshold of 75 mV was established.

5.6 DATA COLLECTION

The UUTA system was used to perform DGM for the detection of MEC within the 250 acre survey area (**Figure 4-1**). The field test was performed in water depths ranging from 1.5 to 7 m. Data collection occurred across approximately 1.5-mile long transects that functioned as virtual grid lines. These grid lines were approximately parallel to the shoreline, and were spaced 2 m

Figure 5-4: GPS Base Station and Launch Location Map

Figure 5-5: Target Calibration Test Results



apart. The UUTA system contains two EM sensors that record data at the coil center of each coil resulting in data paths spaced 1 m apart. A total of 392 km (243.6 linear miles) of data were collected during the demonstration (**Figure 5-6**). Based on the 1 m individual sensor width, a calculated total of 96.9 acres (39.2 hectares) were collected.

Time-Domain electromagnetic (TDEM) data, GPS positional data, water depth, and sensor array depth data were recorded during the field test from May 17 to June 23, 2010. TDEM data were collected at a rate of 18 samples/sec/sensor. Average boat speed was calculated at 3.6 mph (1.6 m/s) during data acquisition. The boat speed and sampling rate produced an average of 11.1 samples/m (3.4 samples/linear ft) along the surveyed grid lines. Boat speed was monitored during data collection to assure acceptable data density was maintained.

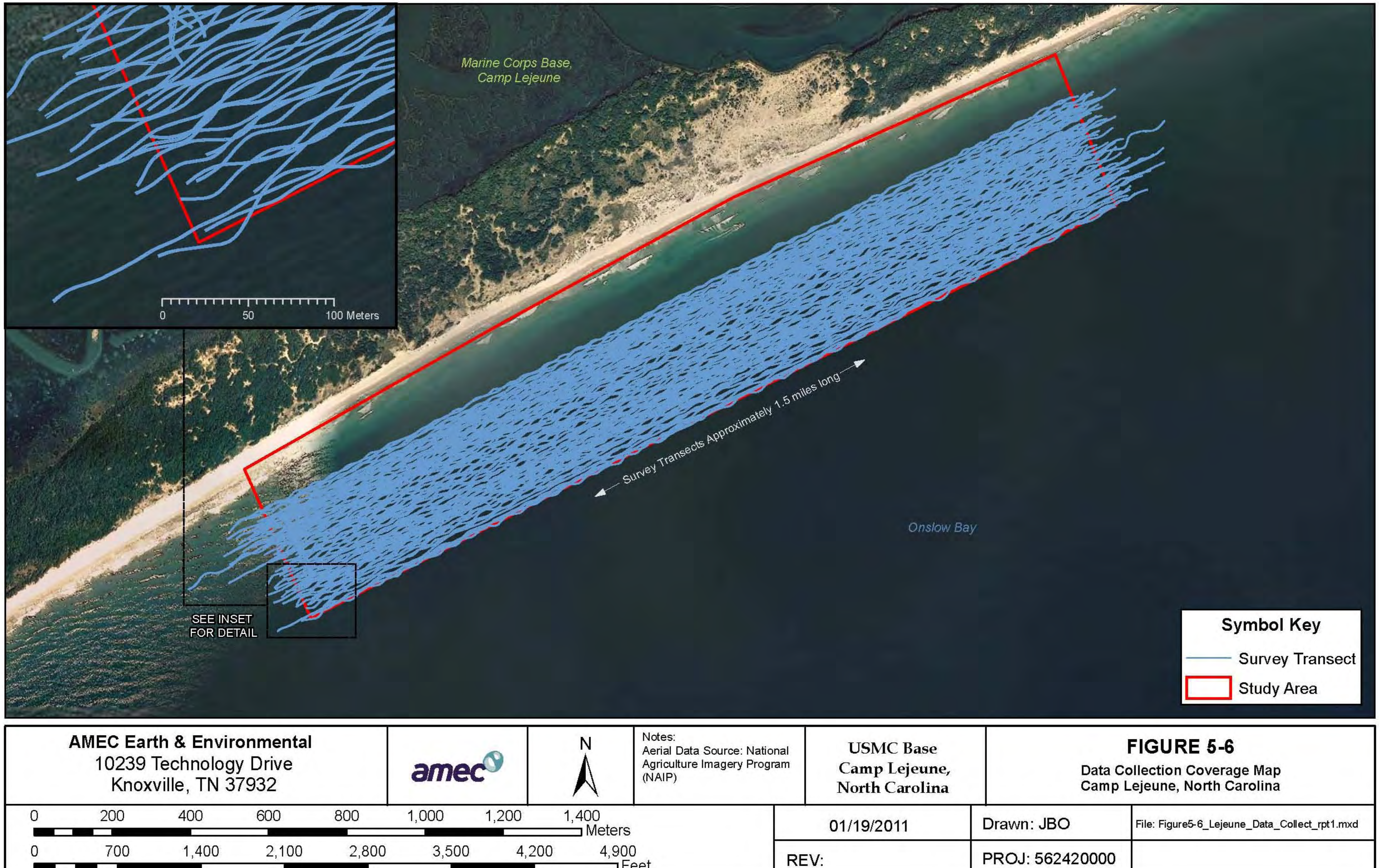
5.6.1 Survey Methodology

The field survey process as described in the demonstration plan was modified. Data coverage was planned to begin on the seaward end of the chained IVS and proceed in a systematic progression toward shore. The intent was to collect data that would cover the seed items on the IVS, and subsequently produce a target list that was purposely biased toward the shallow water. It was presumed that shallow water targets would be easier and faster for the OER reacquisition dive team to most accurately reacquire, and therefore more targets could be validated. It was further intended that the deepest portions of the survey area (on the seaward side of the IVS) would be surveyed as tides and weather permitted, and no data would be collected in the surf zone immediately adjacent to the shore.

Field conditions and preliminary data results required a change in the original data acquisition methodology. The first problem encountered was the change in water depth within the survey area. At the time of the initial site visit in 2009, water depth measurements in the proposed survey area were made and the many aspects of the survey methodology were based upon that data. Upon arrival at the site in 2010 for the field demonstration it was determined that water levels were lower than previously measured by as much as 2.4 m. It was later learned that at the time of the site visit in 2009 the area was experiencing higher than normal tidal activity while at the time of the demonstration in 2010, the area was experiencing lower than normal tidal activity. As a result, the surf zone extended further seaward into the primary study area than intended. This condition reduced the chosen survey area from 250-acres to approximately 180 acres (73 hectares). In addition this fact meant that 1/3 of the IVS seed items would be located in the surf zone that was inaccessible to the boats. Because of the shallow water and the safety concerns caused by the surf zone, almost 2/3 of the survey area spanned by the IVS could only be accessed during the calm conditions.

Because IVS deployment was delayed for 10 days at the beginning of the project (Section 5.3) and because of the extended shallow water surf zone, data collection actually began in the deeper portion of the survey area located further seaward than the proposed IVS anchor location. At this time some data were actually collected outside the bounds of the official study area (in what was later termed the ‘secondary’ study area) because the project team resisted collecting data within the actual survey area before the IVS it was deployed. Once it became apparent to the project team that IVS deployment would be delayed the decision was made to collect data within the bounds of the original study area but outside of the area to be spanned by the IVS.

Figure 5-6: Data Collection Coverage Map



Once data collection within the study area began preprocessing of the survey data also commenced. Preprocessing of the initial survey data in the original study area indicated that almost no target EM anomalies were being encountered. At this time the project team further questioned local residents and Camp Lejeune personnel about the expected density of MEC in the survey area. Although no concrete conclusions were reached, it was predicted by some parties that much of the suspected MEC in the area may have already been removed by commercial fishing activities. The project team became concerned that insufficient target anomalies would be mapped to produce a statistically relevant sampling for the demonstration to meet performance objectives.

To improve the probability of encountering target anomalies, the decision was made by the project team to change the survey methodology from 100% survey coverage to transects spaced several meters apart; similar to wide area assessment surveying. The project team decided that wide area assessment surveying would allow a greater portion of the survey area to be sampled more rapidly. The benefit of the survey methodology change was that if it was determined that limited UXO existed in the survey area, or there was a greater density of UXO in a specific portion of the survey area, then the survey area bounds could be changed while there was still time left in the field schedule. However, a disadvantage of the methodology change was that the possibility existed that some, or perhaps many IVS seed items would not be encountered during data collection.

As previously described, a virtual survey grid had been established across the survey area using lines parallel to shore that were spaced 2 m apart. Using the revised wide area assessment methodology, surveying began by collecting data along every 10^{th} survey line beginning in the most seaward side of the survey area. Survey lines were collected in a systematic progression proceeding toward the shore until the surf zone was encountered. Surveying continued throughout the duration of the demonstration using a similar progression with the exception that data collection began on a different survey line at each successive pass through the survey area.

On two days during which the original survey area was unavailable due to sea state (June 3 – 4, 2010) , the survey team collected data in the intercoastal waterway adjacent to the study area. At this time the project team was still concerned about the lack of potential target anomalies in the study area, and decided to use the down time to evaluate the waterway's potential as a new survey area in the event that a change was required. UXO detection surveys have previously been performed in this waterway at Camp Lejeune, and it was known that MEC contamination there is high. The waterway is included in what was later termed the secondary survey area. As wide area assessment surveying continued in the original (primary) survey area, preliminary analysis of the data indicated that the density of potential EM targets had increased to a level that the project team determined would satisfy the requirements of the demonstration. As a result data collection in the secondary survey area ceased; no other data were collected in the waterway after June 4. Because this surveying was outside the original scope of the demonstration, data collected in the secondary survey area was not analyzed but has been archived.

5.6.2 Demonstration Schedule

It was expected that sea conditions would vary on a daily basis and the window of opportunity for data collection would be small and dynamic. This assumption was correct. During the six

week period of this demonstration, the 3Dg crew and the OER safety boat remained on standby until sea conditions were acceptable for data collection. The intent of the field test was to collect as much data as sea and weather conditions allowed during the scheduled demonstration.

The field schedule was interrupted on several occasions as a result of unfavorable sea state and weather conditions, Camp Lejeune exercises in the survey area, and on one occasion repairs to the Geonics EM-61 receiver coils. The survey crew and safety team met each morning at 6:00 am to begin field activities. During the demonstration it was observed that the sea state generally became more unstable during the afternoon hours. On many days, data collection was terminated as a result of unfavorable or unsafe sea state during early afternoon. Minor repairs and maintenance were required on the UUTA system throughout the demonstration. The system maintenance and repairs had minimal impact on the schedule as all work was completed in less than 24 hours, and the majority before the next day's scheduled activities. The lone exception was the failure of the EM61 receiver coils, which is further described below. Data collection was interrupted for six days as a result of scheduled Camp Lejeune base activities that prevented access to the survey area. **Table 5-6** summarizes the work schedule during the demonstration.

Table 5-6: Geophysical Field Demonstration Schedule Summary

Category	Description	No. of Days
Data Collection (total: 18)	Primary Survey Area	12
	Secondary Survey Area	6
Non Data Collection (total: 22)	Project Tasks	6
	Sea State / Weather	6
	Camp Lejeune No Access	6
	System Repairs	2
	Crew Time Off	2

Early in the demonstration on May 30 the receiver coils on the Geonics EM61 became contaminated with salt water. Data collection was interrupted for two days (June 1 – 2) while a member of the 3Dg crew traveled to the Geonics manufacturing facility to return the faulty system, and test and hand-carry a replacement coil set back to the site. During this surveying interruption the chained IVS was deployed. The cause of the salt water intrusion into the coil complex was later determined to be a manufacturing defect that has since been corrected by Geonics.

5.6.3 Field Demonstration Standard Operating Procedures

The following is a summary of the standard operating procedures that were implemented during the performance of the field test:

1. Determine if sea state and weather conditions were acceptable for DGM

- If yes, continue procedures
- If no, crew remains on standby

2. Standardize Instruments
   - RTK GPS Position Tests
   - EM61 Static and Standard Test
3. Load virtual survey grid into boat navigation system
4. Travel to survey area
5. Reacquire and reoccupy starting grid line position
6. Collect DGM data along virtual grid lines using UUTA system

5.6.4 Quality Checks

Each day, prior to deploying the UUTA system, initial quality control was performed on land to test the system static EM response and the GPS receiver accuracy. The system static test consisted of collecting data for 1 minute without an ISO item, then 1 minute with an ISO item placed under each of the EM61 coils, and 1 minute again without an ISO item. The static test data were analyzed using a quality control tool in Geosoft Oasis Montaj. At least 95% of the data collected without an ISO item must be within +/-5 mV, and at least 95% if the data collected with an ISO item must be within 10% of the expected average. System static QC test results are presented in Appendix B.

Upon deployment in the survey area the DGM data were continuously reviewed by the UUTA system operator during data collection. For EM61 sensor data, static noise levels are on the order of 2.5 mV peak-to-peak (PP). Sensor “spikes” can occur if the height of the sensor is abruptly changed during data collection; such as the sensor platform hitting the ocean bottom. If a sensor cable is severed or damaged while in motion, the sensor output value become very noisy (1,000s of mV PP) and/or output will cease. The EM data were examined in each survey file set for these conditions, and any data that was deemed unsatisfactory was flagged and not processed further.

For location data, the RTK GPS receivers present a Fix Quality (FQ) value that relates to the quality/precision of the reported position. A FQ value of 4 (RTK Fixed) is the best accuracy (typically 3 - 5 cm or better). An FQ value of 5 (RTK Float) indicates that the highest level of RTK has not been reached yet and positional accuracy can be degraded to as poor as ~1.0 m. FQ 1 and 2 are Autonomous and DGPS respectively. Data collected under FQ 4 and FQ 5 (at the discretion of the data analyst) was retained. Any other data was deemed unsatisfactory, flagged, and not processed further.

5.6.5 Data Handling

The DGM data were initially stored in a personal computer (PC) data logger during data collection on the boat. At the end of each field day, the DGM data were downloaded into a PC workstation for on-site review and post processing. In addition, a copy of the field data were electronically sent daily to the 3Dg offices for backup and archival.

5.7 VALIDATION

Accurate validation of DGM data was integral to the success of the technology demonstration. Reacquisition of marine DGM targets poses many logistical problems, especially when water depth exceeds 1.5 m. Much care was taken in formulating the reacquisition and validation procedures prior to the demonstration. These procedures were re-evaluated and refined during the field work. 3Dg designed and fabricated an underwater tripod for the reacquisition team to facilitate accurate recording of the reacquired target positions. **Figure 5-7** shows the tripod at 3Dg prior to deployment to Camp Lejeune. Validation activities were monitored with the same attention to detail as the DGM was conducted.

5.7.1 Validation Team, Boats and Equipment

Target reacquisition and validation for the performance objectives described in Section 3 were conducted by OER and AMEC with the use of two boats and seven persons. One boat carried the dive team that was comprised of OER UXO technician personnel with AMEC support. The four person dive team members, former US Navy Explosive Ordnance Disposal (EOD) divers, were certified by the AMEC or OER Diving Program in compliance with AMEC, Inc. Safe Practices Manual for Scientific Diving. The specific roles of the dive team were diving supervisor, tender, diver and standby diver. All divers other than the diving supervisor rotated positions throughout the fieldwork as directed by the diving supervisor. Each diver met the requirements specified in the Health and Safety Plan in order to dive on AMEC company projects. As defined by the Plan, diving activities include skin diving, snorkeling, and diving with self-contained breathing apparatus (SCUBA). The second boat carried the marking and safety team with three persons with the following roles: coxswain, UXO QC Safety officer and survey technician to operate the RTK GPS. The latter two persons were provided by AMEC while the coxswain was from OER. The photographs in **Figure 5-8** show the boats and validation teams in operation at the site.

The equipment used by these teams included dive gear (snorkels, suits, tanks, etc.), a Bluetooth-enabled RTK-GPS, a JW Fisher Pulse X8 locator, and an underwater camera.

5.7.2 Validation Operations

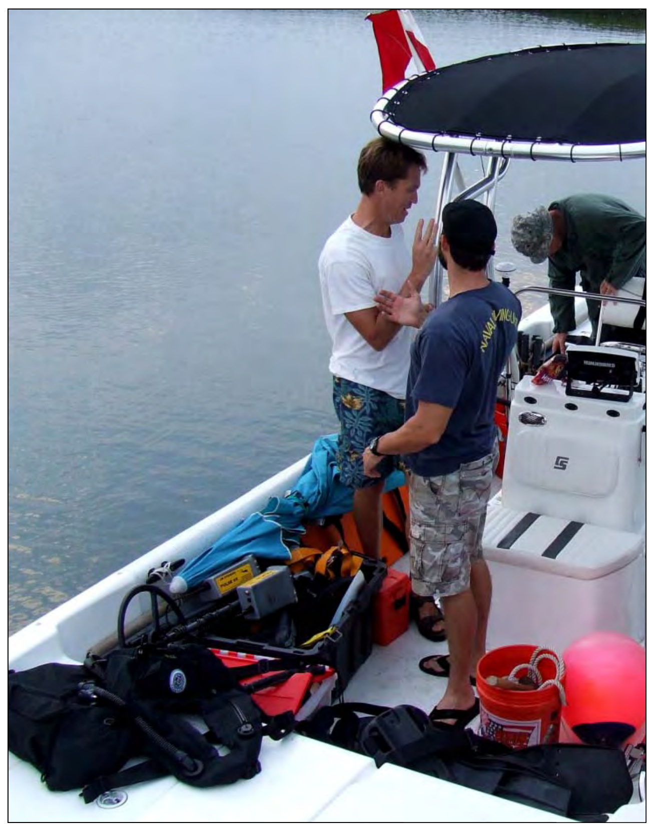
The first operation of the validation team was to test their validation procedures on the seed items along the chained IVS. As a result of the extended surf zone in the survey area only 22 of the 28 seed items could be reacquired by the dive team. The IVS provided an opportunity to refine reacquisition and dive procedures. This included practice of reacquisition procedures, use of the RTK GPS systems, and use of the JW Fisher Pulse X8 locator. This data provided a metric regarding the precision and accuracy of the UXO Dive Team operations. 3Dg assisted the dive teams during this phase for training and operation of the RTK GPS and tripod. OER conducted UXO diving operations to reacquire 57 target anomalies and 22 chained IVS seed items. The operation utilized target anomaly lists provided by 3Dg that were reviewed by AMEC. Standard dive operations set-up and preparation were conducted on a daily basis. The general operations included the following procedures:

1. Standardize instrument by RTK GPS position tests.
2. Enter target anomaly position into RTK GPS controller and travel to location.

Figure 5-7: Tripod at 3Dg Prior to Deployment

Boats after placing GPS receiver

Diver moving GPS receiver over a target



Dive boat with gear and personnel

Figure 5-8**: Boats with Their Teams in Operation at the Site**

3. Marking boat places marker at target anomaly position.
4. Dive boat follows and places diver in water next to marker.
5. Diver obtains Bluetooth-enabled RTK GPS receiver from marking boat.
6. Diver holds GPS in one hand and target marker in other.
7. Survey technician with survey controller guides diver to exact target location and diver drops marker at precise location of target anomaly.
8. GPS returns to boat and diver begins underwater search for target anomaly at sea floor in 2 m radius.
9. If target is visible, the diver obtains camera and records image of item.
10. If target is not visible, the diver uses JW Fisher Pulse X8 all-metals-locator and searches for subsea floor target.
11. When target anomaly is found the diver marks the sea floor with weights to define the extent of anomaly area.
12. The diver then moves the target marker to the center of the anomaly, places the tripod at the anomaly center, and levels the tripod.
13. Diver obtains the GPS from the boat and places it on top of the tripod.
14. The survey technician records the precise location of the target anomaly.

If no target anomalies were detected within the 2m search radius, the position of the center of the search area was recorded with the RTK GPS. After the GPS position was recorded the marking boat departed to set to the next mark. This process continued until the divers were out of air, maximum bottom time was met, or favorable sea-state conditions deteriorated.

In water depths shallower than 1.5 m a level survey rod was used to position the RTK GPS over target anomalies for position recording. Beyond the 1.5 m water depth accurate geo-location of target anomalies was more difficult. In water depths 1.5 m or greater, the stainless steel tripod with a bullseye level designed by 3Dg was used along with the RTK GPS for precise position recording of each target anomaly. The collapsible tripod extended to maximum height of 5.2 m when fully deployed and was designed to receive the GPS receiver over the tip of its center pole while positioned in the water. If it was determined that the difference between reacquired position of the target and the position provided on the Target List by the DGM the was greater than 1 m, then the diver descended on the target again to rechecked the position and level state of the tripod. If the tripod position was found to be in error, it was repositioned and a new GPS position was recorded as previously described. The AMEC UXO Quality Control/Safety Officer was responsible for overseeing the collection of reacquired target anomaly position data.

5.7.3 Recording

Data were recorded for each target anomaly where reacquisition was attempted. Details from this reacquisition process were fully documented. Records collected included the following:

1. Original target data (ID, Northing, Easting, millivolt value);
2. Target reported location (ID, Northing, Easting);
3. Description of reacquired target;
4. Photograph of target; and,
5. Field observations (weather, sea state, difficulties, etc.)

5.7.4 Quality Control/Quality Assurance

All data procedures were provided on a daily and per target anomaly check list. The UXO Technician Quality Control officer reviewed each target anomaly check list daily to ensure that the standard operating procedures were followed.

6.0 DATA ANALYSIS AND PRODUCTS

The following sections detail the analysis steps that were used to produce the final data products that were used to calculate the performance objectives identified in Section 3.

6.1 PREPROCESSING

A data conversion program from Geomar, Inc. was initially used to convert the binary DGM data files (field files) generated by the UUTA data acquisition software into the Geosoft file format. The conversion program calculated a georeferenced position for each data point based on the geometry of the UUTA sensor platform, the GPS receiver, and the bottom depth data. The sensor height above sea floor was also calculated. The converted data files included the following data fields: X position, Y position, EM amplitude (per sensor), sensor depth, bottom depth, sensor height above bottom, GPS fix status, GPS quality (HDOP), and Coordinated Universal Time (UTC) time.

Geosoft Oasis Montaj software was used for all geophysical data processing. At the end of each day of data collection, graphical representations of the daily quality control tests, as well as track plots of the UUTA sensor positions across the survey area were created. The quality control tests plots for both the EM sensor static test and the GPS test were used to document the repeatability of the system (Appendix B and C). The daily track plots were used to monitor data coverage and field productivity. Data processing routines developed by the USACE and available in the UX-Process module of the Oasis Montaj software were used to preprocess the EM data.

Oasis Montaj was also used to preprocess the DGM data, contour the EM data, and identify potential UXO targets. The program identified peak amplitude responses within the contoured (gridded) EM sensor dataset. The processing of the UUTA data included the following:

- Instrument drift correction (leveling);
- System latency and GPS lag correction;
- Digital filtering and enhancement of sensor platform and bottom depth data;
- Sensor platform height calculation;
- Gridding of the EM sensor data; and,
- Preparation of geophysical and target maps.

6.2 TARGET SELECTION FOR DETECTION

Upon completion of the data pre-processing, the geophysical data were gridded to produce an anomaly map. The UXO Detect module of Oasis was used to develop a target database of anomalies within the gridded EM dataset that exceeded the target picking threshold. AMEC and 3Dg prioritized the selected target database and determined a subset of the targets to be used to validate the data. OER conducted UXO diving on the subset of targets to validate the positional accuracy of the mapped anomalies (Section 5.7). The target database was also correlated with calculated positions of the IVS seed items. The positions of seed items located within the collected data coverage area were used to validate the probability of detection for the UUTA

system. The daily data coverage maps and distance traveled data were used to calculate the production rate for the UUTA system.

Any EM anomalies (peak amplitudes) within the data grid that exceeded the target detection threshold were selected as potential targets. Potential targets within a 1 m distance of each other were treated as a single target.

The target detection threshold was determined by the target calibration test (Section 5.5). The highest amplitude targets in the dataset that exceeded the detection threshold were selected for validation. The rationale for picking the highest amplitude targets was to increase the likelihood that the targets could be quickly identified by the reacquisition team. The primary emphasis of the project was to demonstrate the positional accuracy of the UUTA system. To accomplish this goal, a statistically relevant subset of targets required validation. The reacquisition team was limited by budgeted time, weather conditions, and the logistics of the reacquisition procedures as to the amount of the targets that could be reacquired. It was believed that higher amplitude anomalies would most probably represent targets that were either proud of the bottom or buried at a very shallow depth. The target picking threshold was selected by determining the EM amplitude for an object buried at 1 ft (0.30 m) below the sea floor. Taking into consideration the average sensor platform height above sea floor of 2.0 ft (0.61 m), the target picking threshold was set to the EM amplitude corresponding to a separation distance of 3 ft (0.91 m). Based on the target calibration test results (Figure 5-5) the target picking threshold was set at 75 mV. There were 120 target anomalies identified in the acquired DGM data above this threshold. The target quantity of 120 was determined to be more than the reacquisition team could reasonably validate within the demonstration schedule. The dive team validated 57 of the 120 targets during the demonstration.

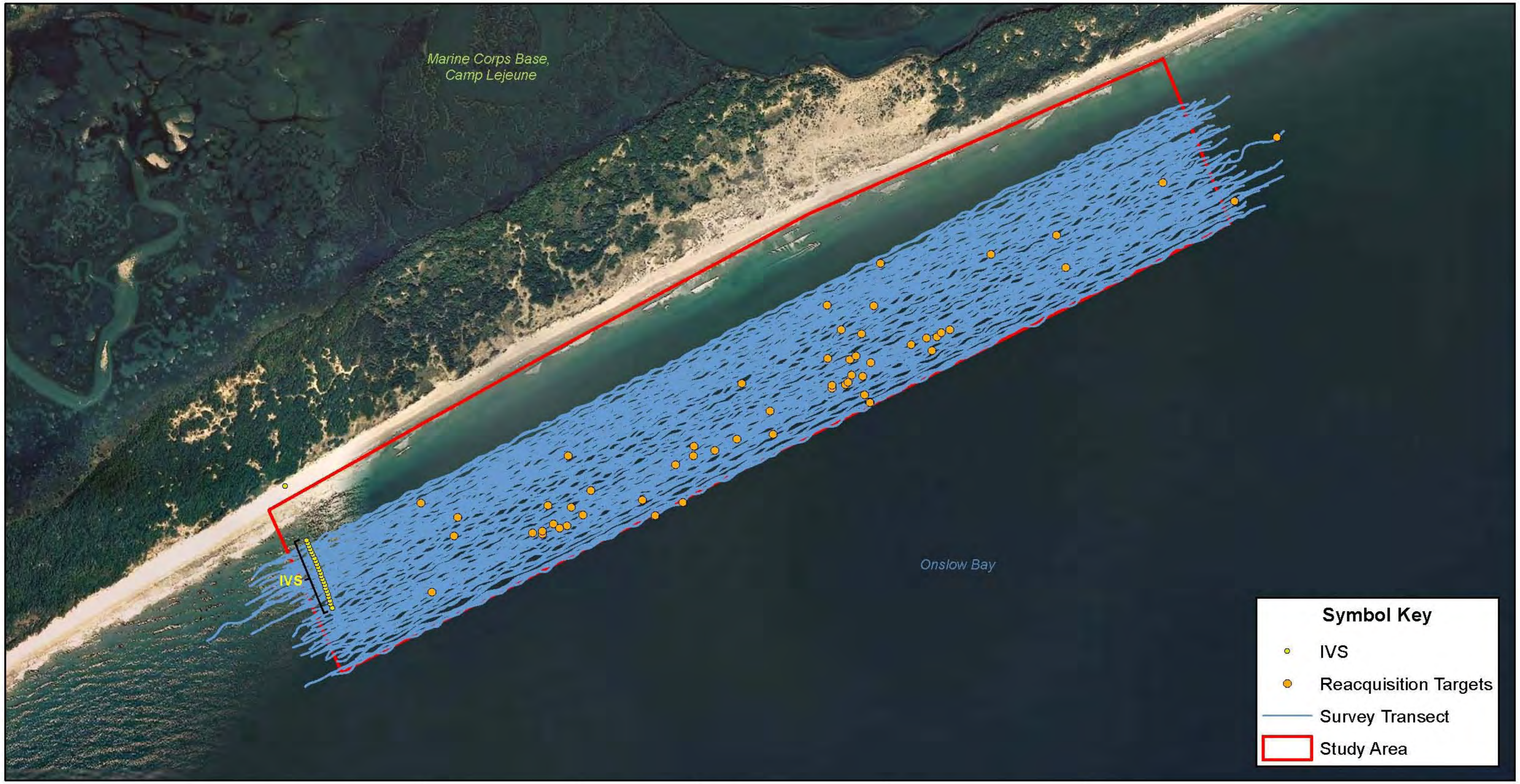
6.3 DATA PRODUCTS

The outputs of the field test data analysis were annotated geophysical anomaly maps of the survey area, data coverage map of the survey area, and a spreadsheet of selected targets (Target List).

The geophysical anomaly maps are plan-view color-contour plots of the gridded EM sensor measurements. The anomaly maps are presented in different map scales to show all portions of the survey area in detail. The anomaly maps are annotated with the locations of selected targets (EM anomalies) and the positions of the seeded IVS items. The geophysical anomaly maps are provided as **Figures 6-1 through 6-4.**

The data coverage map is a plan-view plot of the survey area showing the traveled path of the UUTA sensor array during the field test based on recorded GPS coordinates (Figure 6-1). Interim data coverage maps were produced for every day data were collected during the field test as part of the quality control procedures.

Figure 6-1: Geophysical Anomalies Overview Map



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Notes:
Aerial Data Source: National Agriculture Imagery Program (NAIP)

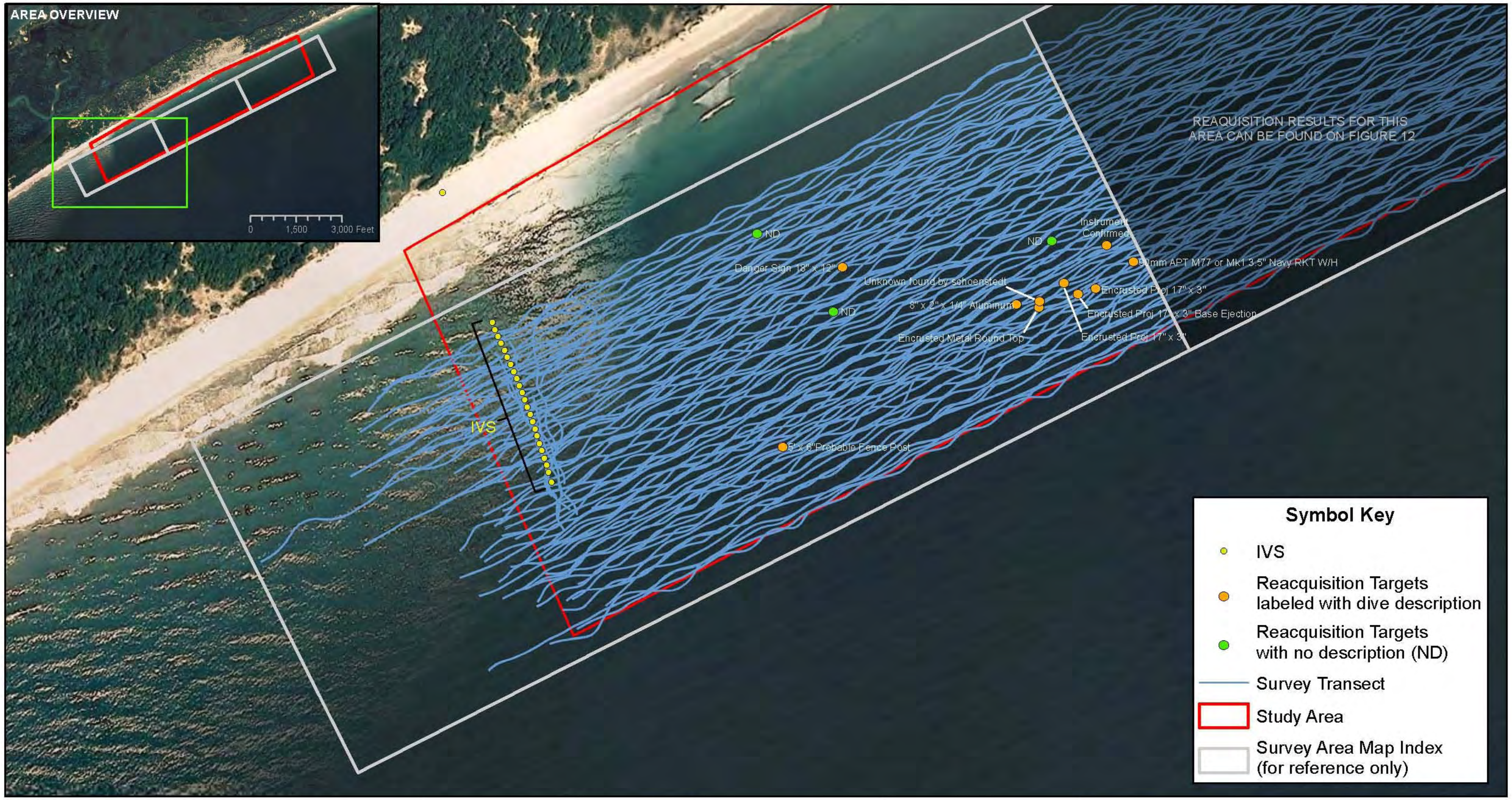
USMC Base Camp Lejeune, North Carolina

FIGURE 6-1
Geophysical Anomalies Overview Map
Camp Lejeune, North Carolina

0 250 500 750 1,000 1,250 1,500 Meters
0 700 1,400 2,100 2,800 3,500 4,200 4,900 Feet

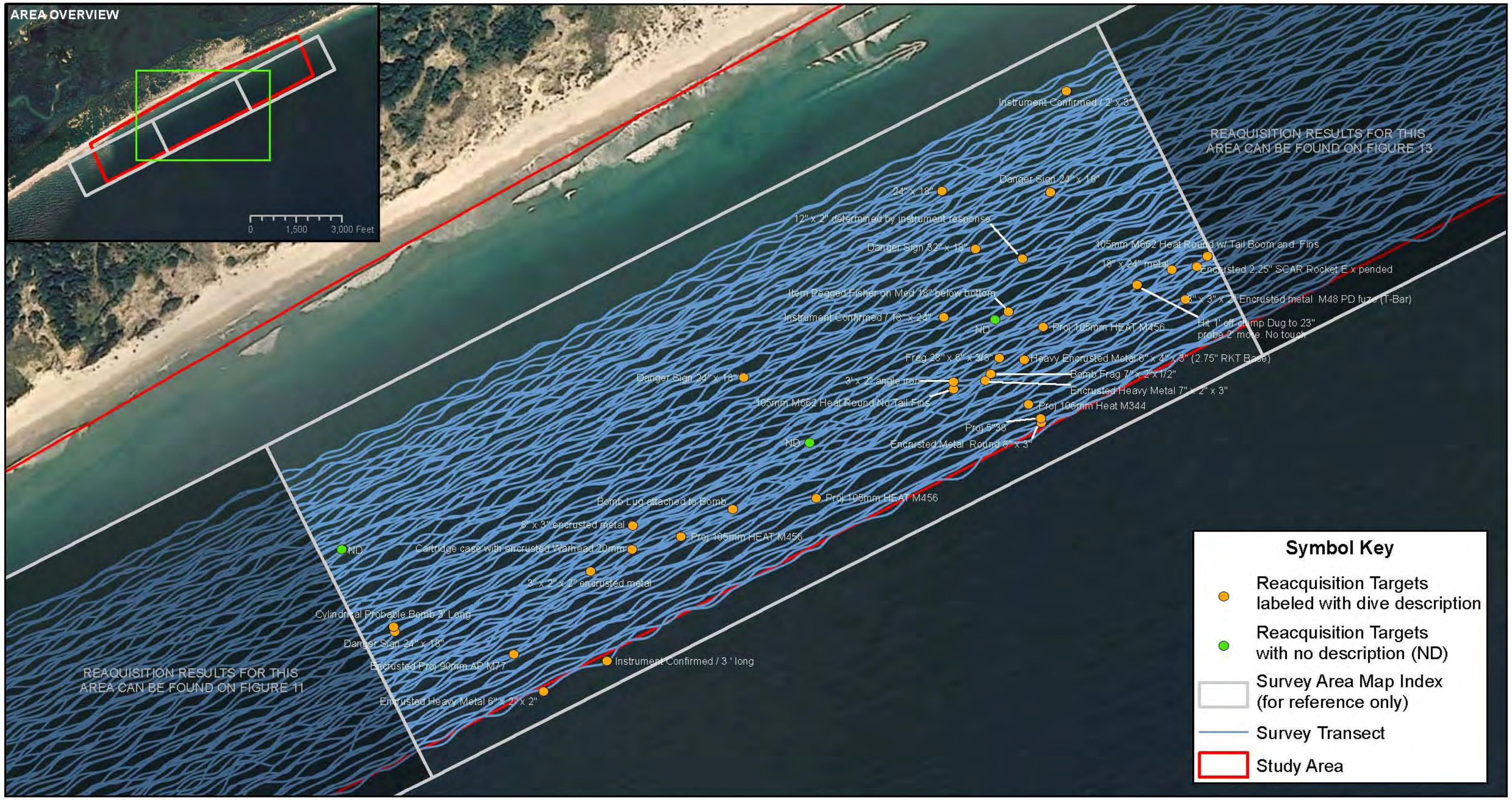
12/10/2010	Drawn: JBO	File: Figure6-1_Lejeune_Overview_Geo_Ano_rpt1.mxd
REV: 01/19/2011	PROJ: 562420000	

Figure 6-2: Geophysical Anomalies Map – Section 1 of 3



AMEC Earth & Environmental 10239 Technology Drive Knoxville, TN 37932	amec	N	Notes: Aerial Data Source: National Agriculture Imagery Program (NAIP)	USMC Base Camp Lejeune, North Carolina	**FIGURE 6-2** Geophysical Anomalies Map - Section 1 of 3 Camp Lejeune, North Carolina
0 100 200 300 400 500 600 Meters 0 300 600 900 1,200 1,500 1,800 Feet			12/10/2010 REV: 01/19/2011	Drawn: JBO PROJ: 562420000	File: Figure6-2_Lejeune_Sec1_Geo_Ano_rpt1.mxd

Figure 6-3: Geophysical Anomalies Map – Section 2 of 3



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Notes:
Aerial Data Source: National Agriculture Imagery Program (NAIP)

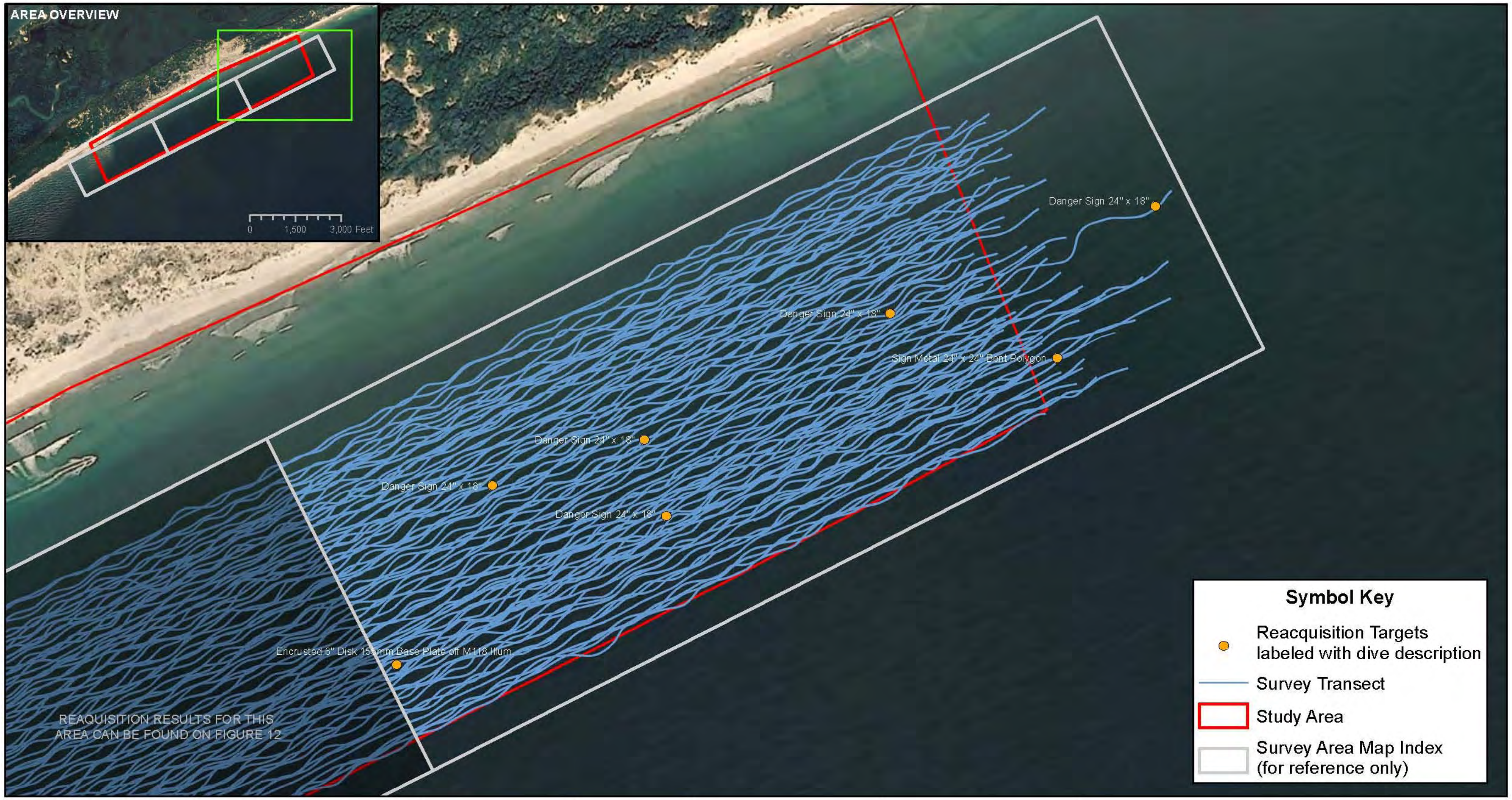
USMC Base Camp Lejeune, North Carolina

FIGURE 6-3
Geophysical Anomalies Map - Section 2 of 3
Camp Lejeune, North Carolina

0 100 200 300 400 500 600 Meters
0 300 600 900 1,200 1,500 1,800 Feet

12/10/2010	Drawn: JBO	File: Figure6-3_Lejeune_Sec2_Geo_Ano_rpt1.mxd
REV: 01/19/2011	PROJ: 562420000	

Figure 6-4: Geophysical Anomalies Map – Section 3 of 3



AMEC Earth & Environmental 10239 Technology Drive Knoxville, TN 37932	amec	N	Notes: Aerial Data Source: National Agriculture Imagery Program (NAIP)	USMC Base Camp Lejeune, North Carolina	**FIGURE 6-4** **Geophysical Anomalies Map - Section 3 of 3** **Camp Lejeune, North Carolina**
0 100 200 300 400 500 600 Meters 0 300 600 900 1,200 1,500 1,800 Feet				12/10/2010 REV: 01/19/2011	Drawn: JBO PROJ: 562420000 File: Figure6-4_Lejeune_Sec3_Geo_Ano_rpt1.mxd

The Target List is a spreadsheet containing the following data fields: target number, X position, Y position, EM value (peak amplitude in milliVolts), bottom depth , data analysts comment. The Target List was provided to the reacquisition team after data processing was completed. The Target List was supplemented with the results of the target reacquisition upon the completion of dive operations. The reacquired target ID, measured X position, measured Y position, diver reacquisition data, and position difference was subsequently added to the Target List. The Target List was divided into two classifications: primary and secondary. The primary list included EM anomalies with amplitudes greater than 100 mV. The secondary list included anomalies with amplitudes between 75 and 100 mV.

7.0 PERFORMANCE ASSESSMENT

A detailed discussion of the performance objectives for the demonstration is presented in Section 3. **Table 7-1** summarizes the performance objectives and results.

Table 7-1: Performance Objectives and Results

Performance Objective	Metric	Data Required	Success Criteria	Results
Positional Accuracy	Number of items reacquired within 1 m of detected position	• Target list with position coordinates • Validation data for selected targets	95% of all recovered and IVS items reacquired within 1 m of detected position	68.3% reacquired within 1 m 95.4% reacquired within 2 m
Production Rate	Number of acres of data collection per day	• Distance platform has traveled and width of transect	5 acres/day	96.9 acres in 12 days (8.1 acres/day [3.8 ha/day] average)
Probability of Detection	Number of IVS items found	• Number of total items within surveyed area • Number of items found	95% of all items detected	Undetermined; only 12 of the 28 available targets were surveyed
Sensor Proximity	Number of EM sensor readings recorded within 1 m of the sea floor	• Sensor array depth • Bottom depth	90% of all EM readings recorded with the sensor array height ≤ 1 m above the sea floor	95.4% of the 4,382,130 sensor readings were ≤ 1 m above the sea floor

7.1 POSITIONAL ACCURACY

The effectiveness of the UUTA system to detect MEC is a function of the system's ability to accurately record the horizontal (X,Y) georeferenced position of mapped EM anomalies. The performance objectives of the demonstration state that the success criteria would be met if the measured GPS positions of more than 95% of the validated targets and IVS items were located within 1 m of the detected (geophysically mapped) positions.

This success criteria was not met, but it is unlikely that all positional accuracy errors can be attributed to the UUTA system (as further discussed below).. A total of 63 dive targets were validated for positional accuracy (53 target anomalies and 10 IVS items). The validated target list is provided in **Table 7-2**. A description of the reacquired targets is also provided in Table 7-2. A total of 43 of the 63 targets (68.3%) were located within 1 m of the geophysically mapped positions; while 61 of the 63 targets (96.8%) were located within 2 m of the mapped positions. The mean difference between the validated and mapped target positions was 0.87 m. The positional accuracy results are summarized in **Table 7-3** and shown in **Figure 7-1**.

Table 7-2: Validated Target List

Target ID	DGM X	DGM Y	Bottom Depth ft (m)	EM lvl mV	Reacquisition X	Reacquisition Y	Difference ft (m)	UXO Diver Description
2	297943.217	3831281.064	18.5 (5.64)	124.2	297942.6753	3831282.155	4.0 (1.22)	3 ' long
3	297878.646	3831252.803	18.3 (5.58)	144.7	297878.9651	3831251.833	3.35 (1.02)	Encrusted Heavy Metal 6"x2"x2"
27	298375.867	3831520.648	17.7 (5.39)	93.0	298375.8689	3831520.293	1.15 (0.35)	Projo 5"38 Caliber
28	298358.306	3831580.100	16.5 (5.03)	264.9	298359.1911	3831581.169	4.56 (1.39)	Heavy Encrusted Metal 6"x4"x3" (2.75" RKT Base)
29	298016.194	3831405.204	16.7 (5.09)	79.8	298016.3376	3831405.629	1.48 (0.45)	Projo 105mm HEAT M456
30	298809.198	3831913.971	10.8 (3.29)	330.6	298808.9588	3831913.846	0.89 (0.27)	Danger Sign 24" x 18"
36	297641.862	3831232.355	15.8 (4.82)	79.3	297642.174	3831232.607	1.31 (0.40)	Encrusted Projo 17"x3"
37	297730.648	3831310.879	14.3 (4.36)	204.7	297730.1852	3831311.108	1.71 (0.52)	Cylindrical Probable Bomb 3' Long
38	298330.334	3831620.393	14.4 (4.39)	87.8	298329.9079	3831621.079	2.66 (0.81)	Dug 24" unable to determine size or orientation
39	298378.428	3831613.289	16.3 (4.97)	75.5	298378.4409	3831613.761	1.54 (0.47)	Projo 105mm HEAT M456
40	297594.511	3831210.638	15.7 (4.78)	81.8	297594.7833	3831211.263	2.23 (0.68)	8"x2"x1/4" Aluminum
42	298342.927	3831628.184	14.6 (4.45)	194.0	298343.6413	3831628.739	2.95 (0.90)	Item Pegged Fisher on Med 18" below bottom
45	297632.072	3831276.955	13.4 (4.08)	84.4	297630.0055	3831274.914	9.51 (2.90)	Dug 12" No size determined Deep or Small
49	299055.652	3832038.586	9.4 (2.86)	1309.3	299054.8496	3832039.185	3.28 (1.00)	Danger Sign 24" x 18"
50	298151.982	3831442.766	17.0 (5.18)	93.2	298151.4103	3831443.61	3.35 (1.02)	Projo 105mm HEAT M456
51	297848.336	3831287.577	16.9 (5.15)	84.2	297848.5933	3831288.544	3.28 (1.00)	Encrusted Projo 90mm AP M77
53	299221.596	3831994.871	15.8 (4.81)	370.7	299221.6859	3831994.924	0.33 (0.10)	Sign Metal 24" x 24" Bent Polygon
55	299320.139	3832144.184	11.4 (3.47)	455.1	299319.8297	3832145.886	5.68 (1.73)	Danger Sign 24" x 18"
56	297360.898	3831070.797	16.5 (5.03)	233.6	297360.8087	3831070.26	1.77 (0.54)	5'x6"Probable Fence Post
57	297710.808	3831255.293	17.4 (5.30)	132.0	297711.4458	3831254.182	4.12 (1.28)	90mm APT M77 or Mk1 3.5" Navy RKT W/H
59	298287.670	3831554.223	17.8 (5.42)	101.1	298288.184	3831552.118	7.12 (2.17)	105mm M662 Heat Round No Tail Fins
60	298319.444	3831561.479	17.9 (5.46)	192.0	298319.8714	3831560.656	3.05 (0.93)	Encrusted Heavy Metal 7" x 2" x 3"
62	298561.436	3831692.248	17.3 (5.27)	75.9	298561.7251	3831690.656	5.31 (1.62)	Encrusted 6" Disk 155mm Base Plate off M118 Illum.
64	298068.068	3831432.722	17.8 (5.42)	343.7	298067.5141	3831432.682	1.84 (0.56)	Bomb Lug attached to Bomb
65	298325.693	3831568.113	17.9 (5.46)	228.5	298325.6513	3831567.089	3.38 (1.03)	Bomb Frag 7"x2"x1/2"
66	298532.403	3831673.845	17.4 (5.30)	87.8	298532.0038	3831673.442	1.87 (0.57)	Encrusted 2.25" SCAR Rocket Expended
67	298289.620	3831558.956	16.8 (5.12)	126.0	298288.9021	3831559.402	2.76 (0.84)	3' x 2" diver reports feels like angle iron
68	298507.394	3831670.876	16.2 (4.94)	76.1	298507.02	3831670.403	1.97 (0.60)	18"x24" metal
69	298832.008	3831837.635	15.6 (4.75)	327.3	298831.1392	3831838.314	3.60 (1.10)	Danger Sign 24" x 18"
70	297967.856	3831415.256	15.6 (4.75)	117.9	297968.3192	3831416.246	3.58 (1.09_	8" x 3" encrusted metal
71	297684.449	3831269.264	15.0 (4.57)	482.3	297684.6378	3831270.629	4.53 (1.38)	3' long ?
72	297925.459	3831370.998	16.7 (5.09)	152.6	297925.4965	3831371.323	1.08 (0.33)	3" x 2" x 2" encrusted metal

Table 7-2: Validated Target List (continued)

Target ID	DGM X	DGM Y	Bottom Depth ft (m)	EM lvl mV	Reac X	Reac Y	Difference ft (m)	UXO Diver Description
73	297967.037	3831393.018	16.6 (5.06)	186.5	297967.2671	3831392.872	0.89 (0.27)	Cartridge case with encrusted Warhead 20mm
74	298334.406	3831583.720	16.5 (5.03)	95.6	298334.4888	3831582.985	2.43 (0.74)	Frag 28"x6"x3/8"
75	298471.976	3831653.906	16.3 (4.97)	147.0	298472.4048	3831655.269	4.69 (1.43)	Hit 1' off clump Dug to 23" probe 2' more. No touch
77	298279.885	3831622.204	13.1 (3.99)	226.2	298278.9128	3831623.302	4.82 (1.47)	18" x 24" determined by instrument response
80	298384.693	3831749.002	9.7 (2.95)	9009.1	298385.1311	3831747.52	5.05 (1.54)	Danger Sign 24" x 18"
82	298310.891	3831691.077	10.1 (3.08)	555.7	298310.4595	3831691.355	1.67 (0.51)	Danger Sign 32" x 18"
85	298657.564	3831868.209	8.4 (5.61)	10880.1	298657.0428	3831868.33	1.77 (0.54)	Danger Sign 24" x 18"
86	297105.765	3831110.205	11.0 (3.35)	316.4	297105.8208	3831109.71	1.64 (0.50)	IVS
89	297123.077	3831059.720	11.5 (3.51)	75.9	297122.7605	3831059.148	2.13 (0.65)	IVS
90	298356.991	3831683.038	12.7 (3.87)	114.0	298357.0509	3831681.57	4.82 (1.47)	12"x2" determined by instrument response
92	297730.327	3831309.618	16.1 (4.91)	408.8	297729.9009	3831310.869	4.33 (1.32)	Danger Sign 24" x 18"
96	298079.408	3831563.254	13.4 (4.08)	531.0	298078.8864	3831563.21	1.70 (0.52)	Danger Sign 24" x 18"
97	297420.134	3831248.619	12.1 (3.69)	300.3	297420.7608	3831248.304	2.30 (0.70)	Danger Sign 18"x12"
98	297102.910	3831116.990	10.9 (3.32)	120.6	297103.3162	3831116.873	1.38 (0.42)	IVS
99	298276.638	3831748.799	11.3 (3.44)	403.6	298276.7741	3831748.863	0.49 (0.15)	24" x 18"
111	297673.812	3831228.167	17.0 (5.18)	76.9	297673.6352	3831227.303	2.89 (0.88)	Encrusted Projo 17"x3"
152	297076.400	3831180.854	9.5 (2.90)	85.7	297076.5273	3831179.639	4.00 (1.22)	IVS
156	298400.502	3831849.172	10.8 (3.29)	401.7	298401.3158	3831847.687	5.54 (1.69)	2'x3" Determined by instrument Response
167	298362.901	3831537.489	17.7 (5.39)	82.5	298363.2931	3831536.944	2.20 (0.67)	Projo 106mm Heat M344
168	297124.683	3831052.892	10.1 (3.08)	661.0	297124.9643	3831051.851	3.54 (1.08)	IVS
169	298520.155	3831642.407	15.9 (4.85)	114.2	298520.3486	3831641.172	4.10 (1.25)	3"x3"x2" Encrusted metal M48 PD fuze (T-Bar)
171	298376.777	3831518.872	17.7 (5.39)	78.1	298376.4794	3831518.768	1.05 (0.32)	Encrusted Metal Round 8"x3"
172	297656.071	3831220.338	14.7 (4.48)	76.0	297656.3685	3831221.837	5.02 (1.53)	Encrusted Projo 17"x3" Base Ejection
173	297617.166	3831208.113	14.6 (4.45)	92.9	297617.0258	3831208.582	1.61 (0.49)	Encrusted Metal Round Top
174	298541.699	3831683.502	14.6 (4.45)	206.7	298542.0357	3831683.575	1.11 (0.34)	105mm M662 Heat Round w/ Tail Boom and Fins
175	297620.834	3831214.249	14.6 (4.45)	92.1	297617.8989	3831214.821	9.81 (2.99)	Unknown found by schonstedt

Coordinates: World Geodetic System 1984 Universal Transverse Mercator Zone 18 North, Units in Meters.

Figure 7-1: Positional Accuracy

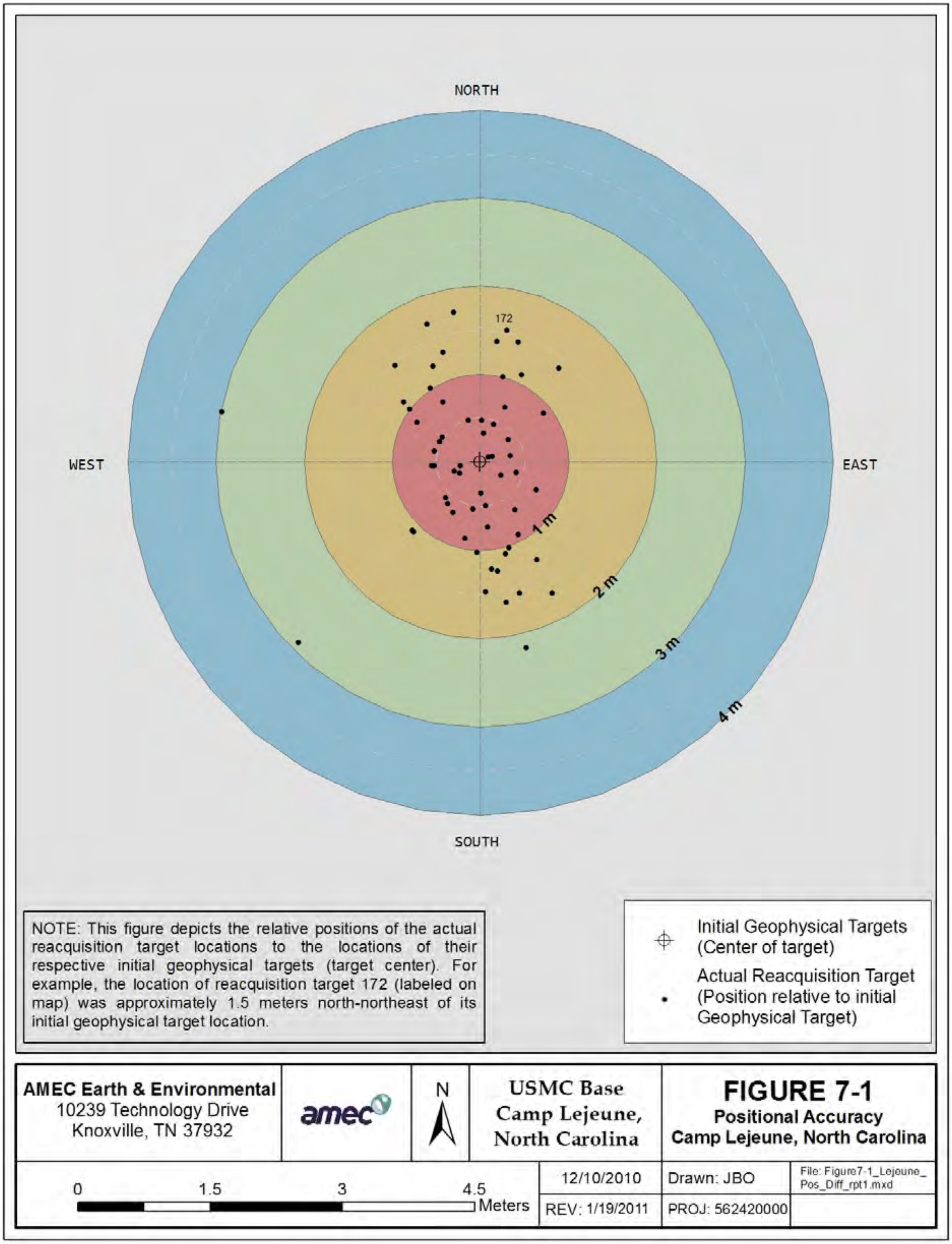


Table 7-3: Positional Accuracy Results

No. of Validated Targets	Measured Positional Accuracy			Mean Difference
	0.0 – 1.0 m	0.0 – 2.0 m	> 2.0 m	
63	43 / 63 targets (68.3%)	61 / 63 targets (96.8%)	2 / 63 targets (3.2%)	0.87 m

A definitive assessment of the positional accuracy of the UUTA system could not be determined because the error associated with the reacquisition process could not be measured. Although errors attributed to reacquisition measurements are negligible for terrestrial surveys, this error can be significant in a dynamic marine environment. At the onset of reacquisition activities the AMEC UXO Quality Control/Safety Officer qualitatively observed that measured positional accuracy of the validated targets decreased as sea state conditions intensified. After this determination the project team ceased reacquisition activities until new reacquisition procedures were formulated (Section 5.6). Although the OER dive team exercised extreme care during the target validation, there is a non-negligible component of the overall positional error that must be considered during the analysis of these data. Unfortunately there were limited data acquired during the demonstration for the purpose of a quantitative analysis of reacquisition error. It was however determined that the mean difference between reacquired and mapped target positions was 0.55 m (1.8 ft) for IVS seed item targets, compared to a difference of 1.07 m (3.5 ft) for all other targets. The IVS seed items were all located in less than 4 m of water, and the positions of these seed items were collected on a calm days. Subsequent to this demonstration, 3Dg has performed other marine MEC detection surveys using the same UUTA system. These projects have incorporated a daily QC test that measures positional accuracy by collecting data over the location of a single seed object placed on the sea floor. These QC data have been collected in various wind and sea state conditions at different project sites over many days. Average positional error for these QC tests has been calculated at approximately 0.5 meters. All of the currently available qualitative and quantitative data suggest that a significant percentage, perhaps as much as 50% or more, of the reported positional error during the demonstration may be attributable to reacquisition error.

7.2 PRODUCTION RATE

The effectiveness of UUTA system for DGM is a function of the system's ability to rapidly collect data over large survey areas. The performance objectives of the demonstration state that the success criteria will be met if the calculated production rate of the system exceeds 5 acres per day during the demonstration.

The success criteria were met. A total of 243.6 linear miles of data were collected during the demonstration. Based on the 1 m (3.28 ft) sensor width, a calculated total of 96.9 acres (39.2 ha) were collected. Validated data were collected on 12 days during the demonstration. The calculated production rate for the demonstration was 8.1 acres/day (3.3 ha/day).

7.3 PROBABILITY OF DETECTION

The effectiveness of the UUTA system for the detection of MEC is a function of the system's ability to record EM anomalies (detected targets) over a high percentage of seeded target items. The performance objective of the demonstration state that the success criteria for PD will be met if more than 95% of the validated IVS seed items are detected during the DGM.

The success criteria were undetermined. The chained IVS consisted of 28 seeded target items. However, DGM data were only collected within 0.5-meter of 12 of the 28 targets. Target responses were observed over 10 of the 12 mapped seed items (83.3%). The probability of detection results are summarized in **Table 7-4.**

Table 7-4: Probability of Detection Performance Results

Total IVS Seed Items	Seed Items Within DGM Coverage	Seed Items Identified as Targets	Probability of Detection
28	12	10	83.3% *

* This calculated value is not statistically significant

Almost 30% (8 of 28) of the IVS seed items were inaccessible during the DGM because they were located too close to the shore and within the surf zone. As a result of the lack of targets identified in the DGM data during the early stages of the demonstration, the data acquisition methodology was changed from attempting 100% volumetric coverage to wide area assessment (transect) surveying (as discussed further in Section 5.6). The sensor platform only encountered 12 of the 28 seed items because of this change. During data collection over the 2 seed items that did not produce EM targets in the dataset, the sensor platform height was not within optimum data recording specifications (the platform was greater than 1 m above sea floor). A total of 12 seed items does not represent a statistically significant sampling to calculate the probability of detection for the system.

7.4 SENSOR PROXIMITY

The effectiveness of the UUTA system for the detection of MEC is a function of the system's ability to control and record the vertical position of the sensor platform. The performance objectives of the demonstration state that the success criteria will be met if the calculated sensor height above sea floor is less than or equal to 1 m (3.28 ft) for more than 90% of the EM sensor readings. The sensor height above sea floor calculation was made by subtracting the measured platform depth from the measured bottom depth at every EM sample position.

The success criteria were met. A total of 4,382,130 unique data points were collected during the DGM, and 4,180,552 points had a calculated height above seas floor of 1.0 m (3.28 ft) or less (95.4%). The mean sensor height was 0.61 meter (2 ft). The sensor proximity results are summarized in **Table 7-5.**

Table 7-5: Sensor Proximity Performance Results

Total Data Points	Pts with Sensor Height ≤ 1.0 m	Sensor Proximity Success %	Mean Sensor Height
4,382,130	4,180,552	95.4%	0.61 m (2.0 ft)

8.0 COST ASSESSMENT

This type of marine geophysical survey in an open sea setting has rarely been performed. The cost of the survey depends upon a number of factors. These include:

- Deployment vessel transportation to the site, fuel costs, and survey area access.
- Total size of the proposed area to be surveyed and length of the proposed survey lines.
- Extent of wave action, rip currents, winds and weather that can influence data collection productivity.
- Location of the site, which can influence the cost of logistics.
- Travel distance between vessel launch location and the survey area.
- Scouting, creating and maintaining a suitable GPS base station location.
- Survey objectives and density of coverage, specifically high density for individual ordnance detection (100% coverage) versus transects for target/impact area delineation and footprint reduction (wide area assessment).
- Safety requirements, specifically the need for a companion safety boat

The costs for underwater UXO surveys in an oceanic environment lie largely in logistics. Much time is used for activities other than data collection. Some of these activities include performing on-land QA/QC procedures, launching the vessel, and ferrying the vessel to and from the survey area, and stand-by time for unacceptable weather or sea state conditions. For this demonstration launching the UUTA system and ferrying it on an approximate 3-mile path through the intercoastal waterway and surf was a challenging and time-consuming task.

Data coverage requirements also greatly affect survey costs. It is obvious that 100% data coverage surveys require greater time and resources than wide area assessment surveying. As currently configured the UUTA system acquires data along a 2 m wide array path. In a dynamic marine environment with wave action, rip currents, and winds detailed effort would be required to attempt full data coverage. For the purposes of this demonstration and cost assessment only the wide area assessment approach is evaluated.

8.1 COST MODEL

Cost information associated with the demonstration of the UUTA marine EM metal detection system was tracked and recorded from the onset of the contract through the testing phase, the field demonstration, the validation (reacquisition), data processing and preparation of the demonstration report. These costs provided the data necessary to prepare the cost model. **Table 8-1** summarizes the various cost elements that were recorded for the project. However, not all project costs are reflected in the table. Project management, oversight, additional ESTCP reporting and other incidentals are not included in Table 8-1.

Table 8-1: Cost Summary

Cost Element	Data Tracked During Demonstration	Estimated Costs ($K)
Geophysical Equipment Testing	Initial Geophysical Equipment Testing – Travel, Equipment integration, reconfiguration, software development*	• 176
Mobilization and demobilization	Cost to mobilize and demobilize to site	• 12
Site preparation	Evaluation Trip IVS Assembly and Installation Work Plan and Logistics	• 17 • 6 • 35
Survey costs	Item Costs: Rental Vehicles Safety Boat Rental – truck, trailer, boat, and fuel Unit Costs: UUTA (boat and equipment) Rental - $2990/day Daily Labor Support – (3 men w/per diem) Safety Diver Support (2 men with per diem) <u>Total Survey Cost (7 Weeks)</u> Cost per acre Number of personnel on survey team	 • 3.2 • 21.6 • 134.6 • 172.6 • 55.3 • <u>387.3</u> • 3.87 • 3 on Survey Boat • 2 on Safety Boat
Reacquisition	Item Costs: Rental Vehicles Survey Equipment Unit Costs: Dive Boat Rentals (2) – truck, trailer, boat, equipment and fuel - $1600/day Daily Dive Support – (5 men w/per diem) Survey Support - (1 man w/per diem) <u>Total Reacquisition Cost (4 Weeks)</u> Number of personnel on Reacquisition team	 • 1.2 • Included in the labor cost • 28.8 • 86 • 15 • <u>131</u> • 5 Divers, 1 Surveyor on 2 Dive Boats
Survey Products	Data processing Survey and Reacquisition Report	• 28.1 • 45

Note: Costs summarized in this table do not reflect the total cost of the project. Some of the costs not captured include project management, oversight, additional ESTCP reporting and other incidentals.
*The equipment testing was a single event to test the system on the boat used on the project. It was a one-time event that will not factor into future surveys.

8.2 COST DRIVERS

The major cost drivers for a marine UXO detection survey are the costs of accessing the site, the number of hours that can safely be utilized for data collection, and the data processing and analysis associated with the acquired data. In terms of tasks, these constitute the majority of the field-related survey costs (i.e. mobilization, data acquisition, and demobilization costs). The in-field survey costs represent the largest cost item for a marine UXO detection survey.

The data collection platform (the entire UUTA system including the tow vessel) is a significant component of the costs associated with the demonstration. This cost element is included in the mobilization, data acquisition, and demobilization tasks. The costs include mobilization, accessing the site, fuel, field crew, maintenance of systems, and per diem and travel for the survey and safety teams. Depending on survey location (distance from home base), mobilization and demobilization costs can be significant when compared to the overall data acquisition cost. Additionally, the type of survey, weather conditions, length of the survey day, weather and sea state stand-by time all affect the data collection costs of the project.

Data processing and analysis functions constitute the majority of the remaining costs associated with the field demonstration.

The variability of the cost drivers may be modeled under several different project differences. Survey time and equipment cost is typically on a daily basis. The size of the site to be surveyed can vary. The amount of time spent mobilizing to and from the site will vary, as will the amount of time required for the survey vessel to ferry from the launch point to the actual survey area. The speed at which data can safely and accurately be collected will also vary based on site conditions. The other major cost drivers mentioned above include equipment and personnel mobilization/demobilization and data processing. These costs are a function of project size and transportation distance, respectively.

8.3 COST BENEFIT

The Cost Benefit of the UUTA system cannot be compared with conventional geophysical surveys, such as land based EM61 or airborne geophysical surveys, because they may not be used in the conditions (depths up to 20 ft [6.1 m] in near shore environments) encountered during this demonstration. However, Table 8-1 provides information for comparison with future underwater surveys with this system.

9.0 IMPLEMENTATION ISSUES

The following sections address potential implementation issues and lessons learned from the technology demonstration.

9.1 REGULATORY ISSUES

Licensing of the towing vessel and permits from the state or country of deployment are required. It will be necessary prior to deployment to identify potential regulations that may apply to the use of the towing vessel in certain lakes, estuaries or the coastal waters. In large part to its non-bottom contact design no environmental regulations are anticipated to restrict the implementation the technology.

9.2 END-USER CONCERNS

The assembly and construction of the downrigging / towing system and deployment may require skilled personnel and machinery. The towing vessel and safety boats require skilled operators. Safety as with any water activity, especially in a dynamic marine environment, is a concern. However, with the proper personnel the operation as demonstrated can be conducted without incident.

9.3 PROCUREMENT AND AVAILABILITY

The UTTA system is a combination of geophysical instrumentation, navigation and positioning sensors, and a deployment vessel that are all commercially available. The acquisition software (Geomar, Inc.) that manages and stores the incoming data, and the processing software (Geosoft, Inc.) are all commercially available products. The cables, winches and materials used to fabricate the downrigging and towing platform are products readily available from commercial vendors. Some components may require long lead times.

9.4 SPECIALIZED TRAINING

Assembly and operation of the UUTA system, and quality control, processing and interpretation of the collected data require experienced and skilled personnel. Validation requires qualified UXO Technicians with Dive Certificates.

9.5 LESSONS LEARNED

The accuracy of the verification of anomalies is dependent upon the depth of water and the current sea state in which this process in conducted. Reacquisition position accuracy diminishes beyond 10 ft (3.05 m) bsl or in wave states greater than 2.0 ft (.61 m). It is possible that 50% or more of the positional error of the EM anomalies validated during the demonstration may be attributable to the implemented reacquisition procedures, especially in deeper water or high seas.

The UUTA system cannot be deployed in sea states with consistent wave heights greater than 3.0 ft (0.91 m).

APPENDIX A

Points of Contact

POINT OF CONTACT Name	ORGANIZATION Name Address	Phone Fax E-mail	Role in Project
Donna Sharp	AMEC Earth and Environmental, Inc. 10239 Technology Drive Knoxville, Tennessee 37932	865-966-4338 x152	Project Manager
Paula Bond	AMEC Earth and Environmental, Inc. 10239 Technology Drive Knoxville, Tennessee 37932	865-966-4338 X 112	Principle Investigator
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Jeremy Haney	AMEC Earth and Environmental 3049 Ualena Street, Suite 1100 Honolulu, Hawaii 96819	Direct: 808-791-0359 Office: 808-545-2462 Cell: 845-405-1512	Geophysicist

APPENDIX B

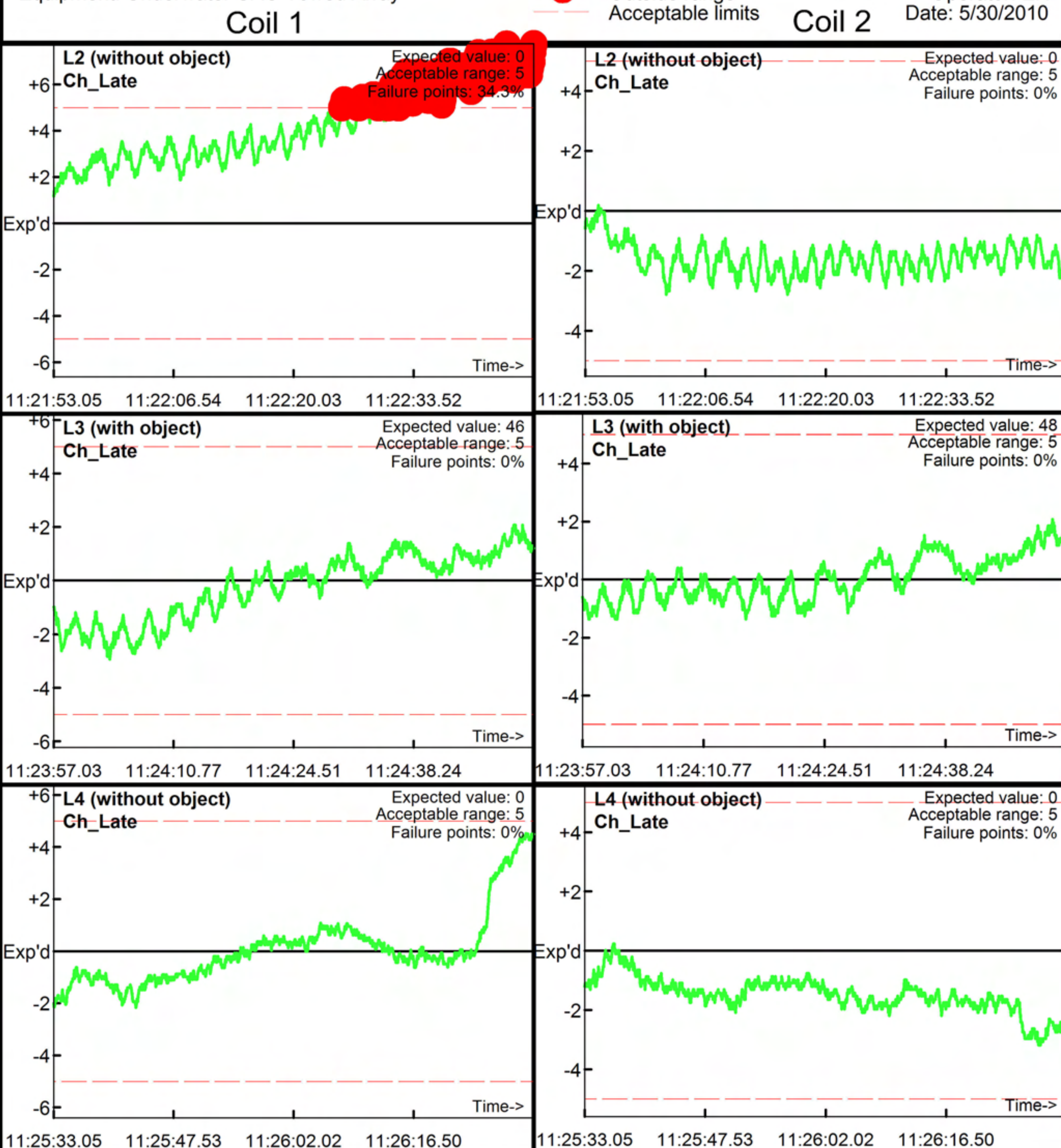
Static Test Results

Static Calibration Test

Project: Camp LeJeune Shallow Water UXO Survey
Equipment: Underwater UXO Towed Array

Allowable failure (%): 5%
Outside range
Acceptable limits

Operator: EK
Date: 5/30/2010



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Line Name: L2 L3 L4

Static Calibration Test

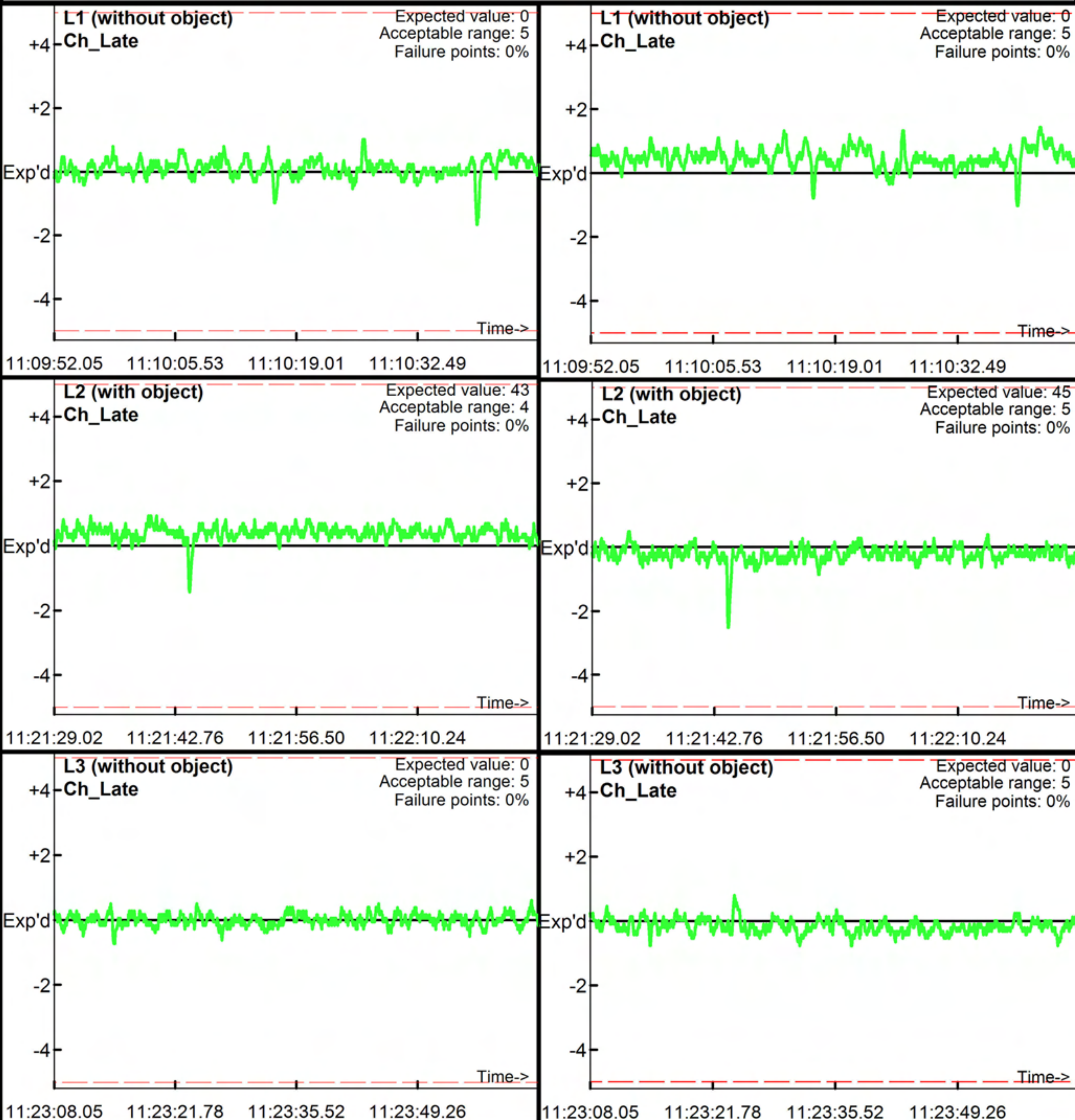
Project: Camp LeJeune Shallow Water UXO Survey
Equipment: Underwater UXO Towed Array

Allowable failure (%): 5%
Outside range
Acceptable limits

Operator: EK
Date: 6/5/2010

Coil 1

Coil 2



Database: C:\GeoSoft-Static_QC\static_060510_L.gdb
Line Name: L1 L2 L3

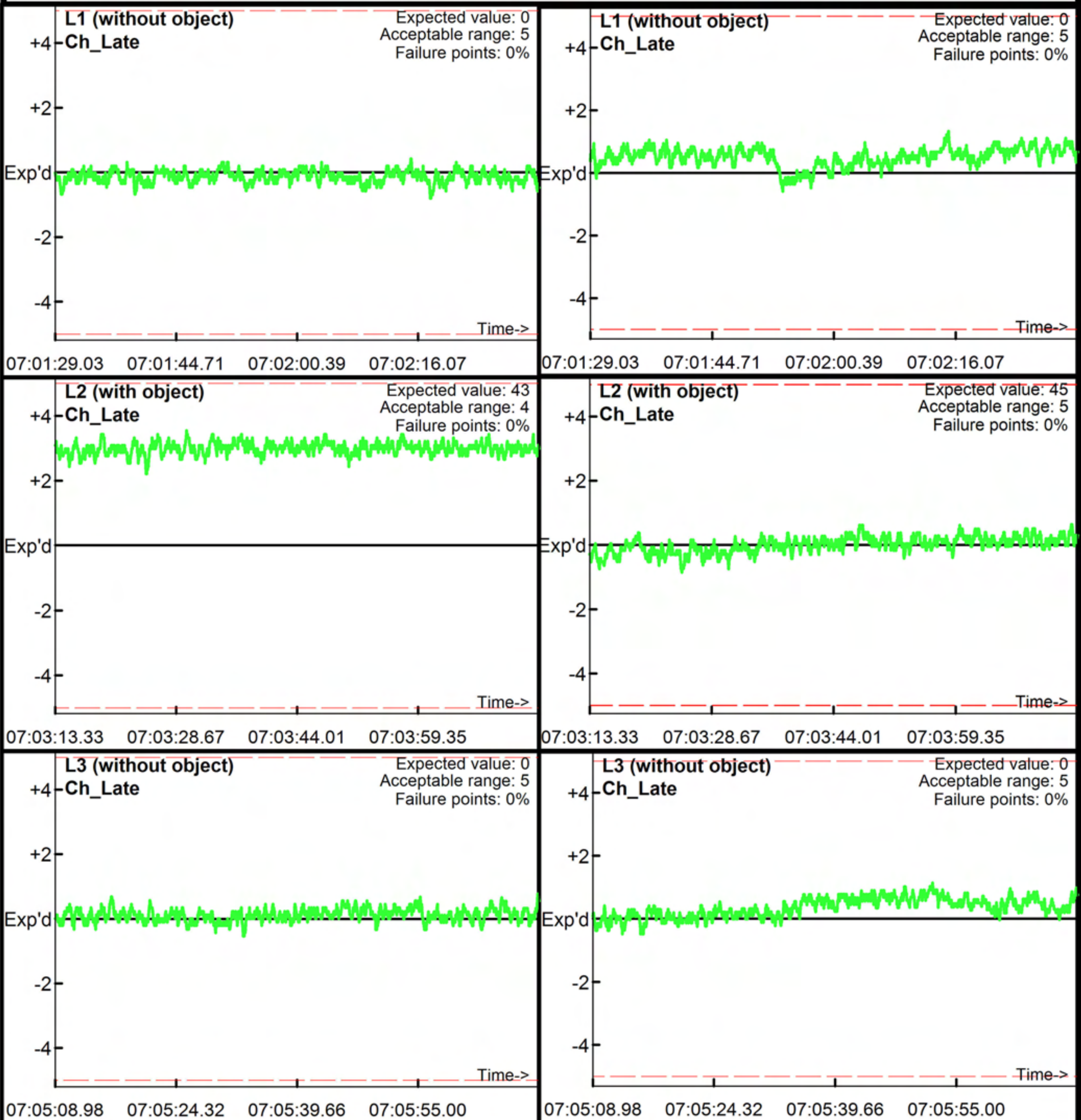
Static Calibration Test

Project: Camp LeJeune Shallow Water UXO Survey
Equipment: Underwater UXO Towed Array

Allowable failure (%): 5%
Outside range
Acceptable limits

Operator: EK
Date: 6/6/2010

Coil 1 Coil 2



Database: C:\GeoSoft-Static_QC\static_060610_L.gdb
Line Name: L1 L2 L3

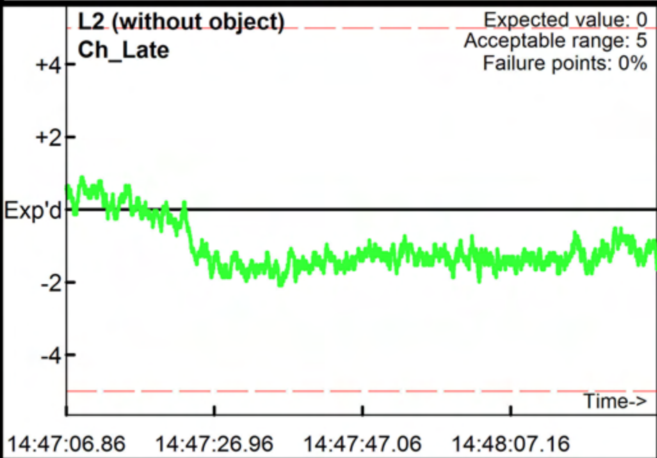
Static Calibration Test

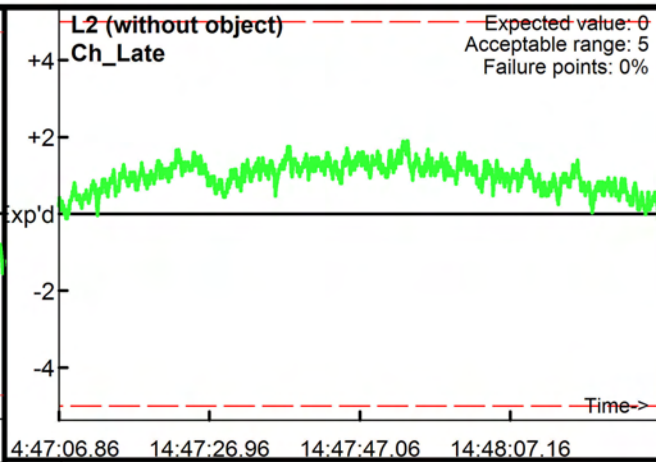
Project: Camp LeJeune Shallow Water UXO Survey
Equipment: Underwater UXO Towed Array

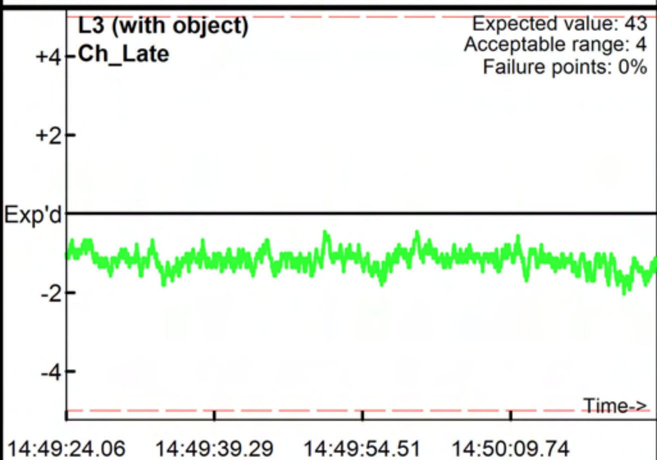
Allowable failure (%): 5%
Outside range
Acceptable limits

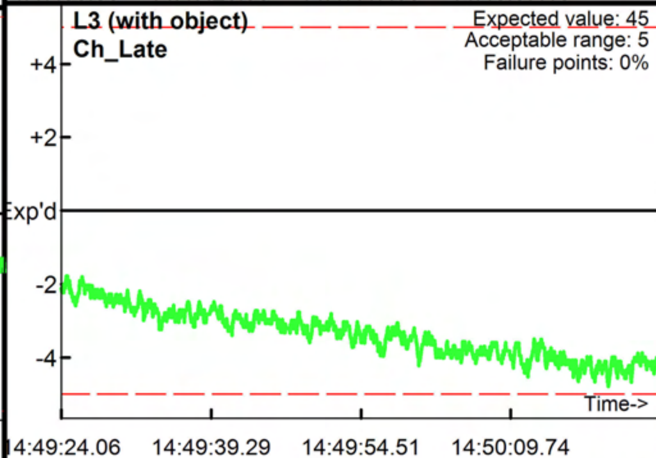
Operator: EK
Date: 6/7/2010

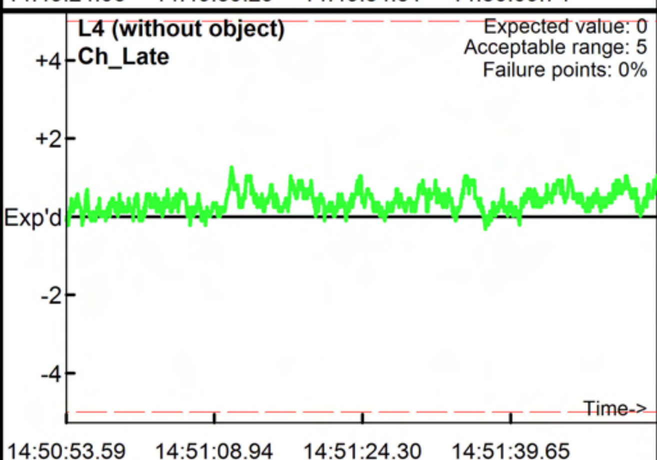
Coil 1 | Coil 2

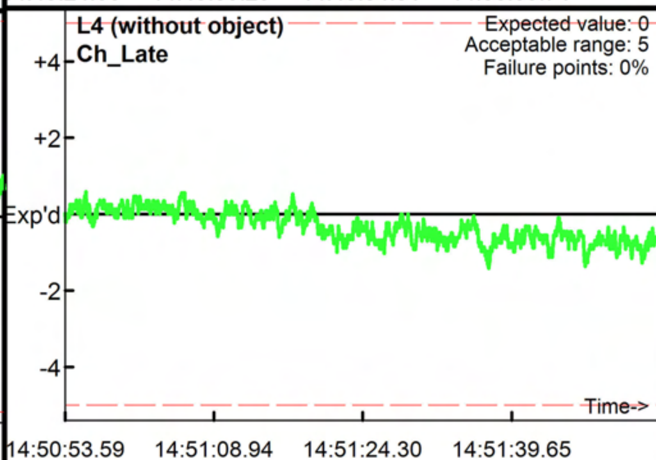












Database: C:\GeoSoft-Static_QC\static_060710_L.gdb
Line Name: L2 L3 L4

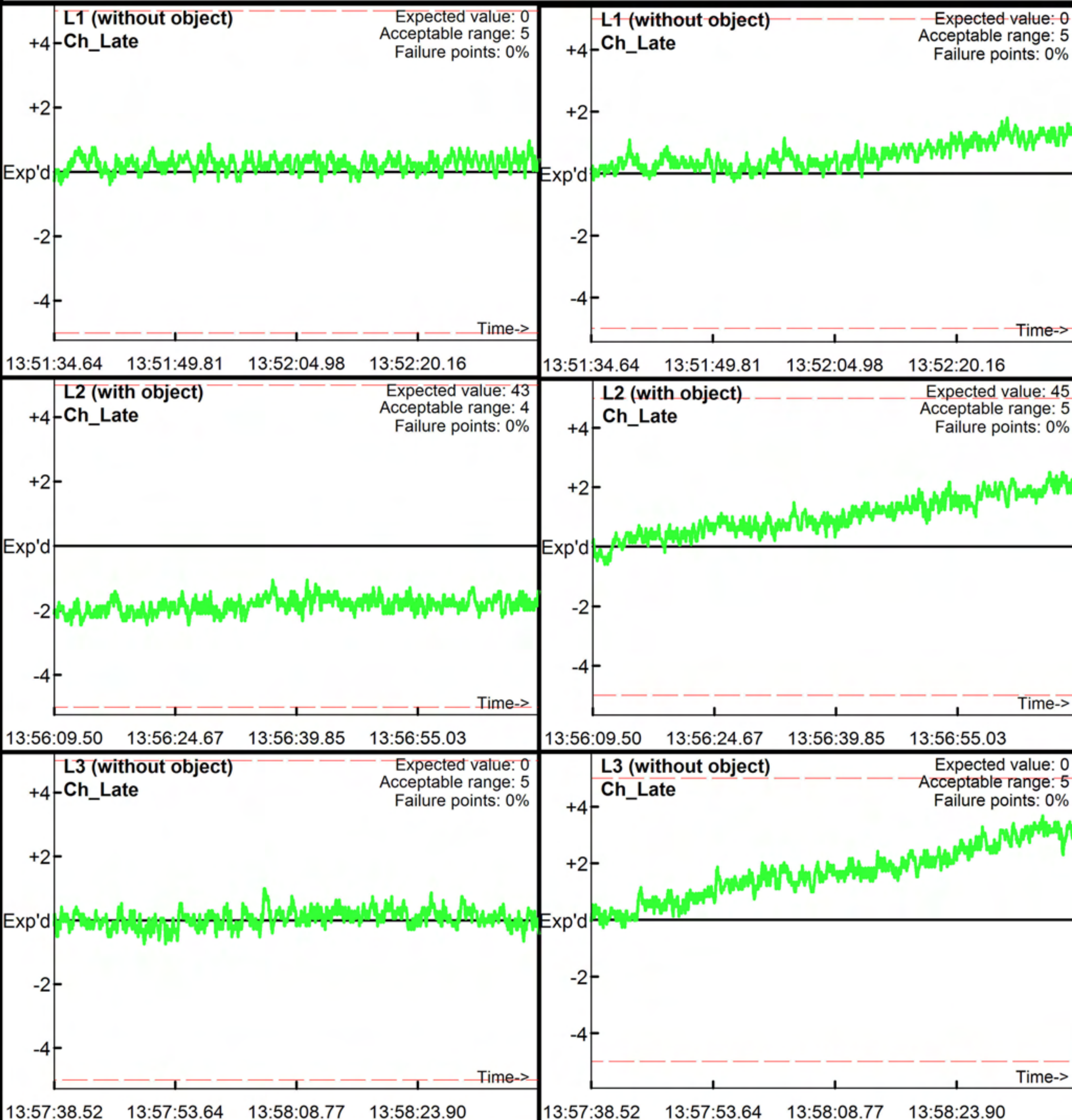
Static Calibration Test

Project: Camp LeJeune Shallow Water UXO Survey
Equipment: Underwater UXO Towed Array

Allowable failure (%): 5%
Outside range
Acceptable limits

Operator: EK
Date: 6/8/2010

Coil 1 Coil 2



Database: C:\GeoSoft-Static_QC\static_060810_L.gdb
Line Name: L1 L2 L3

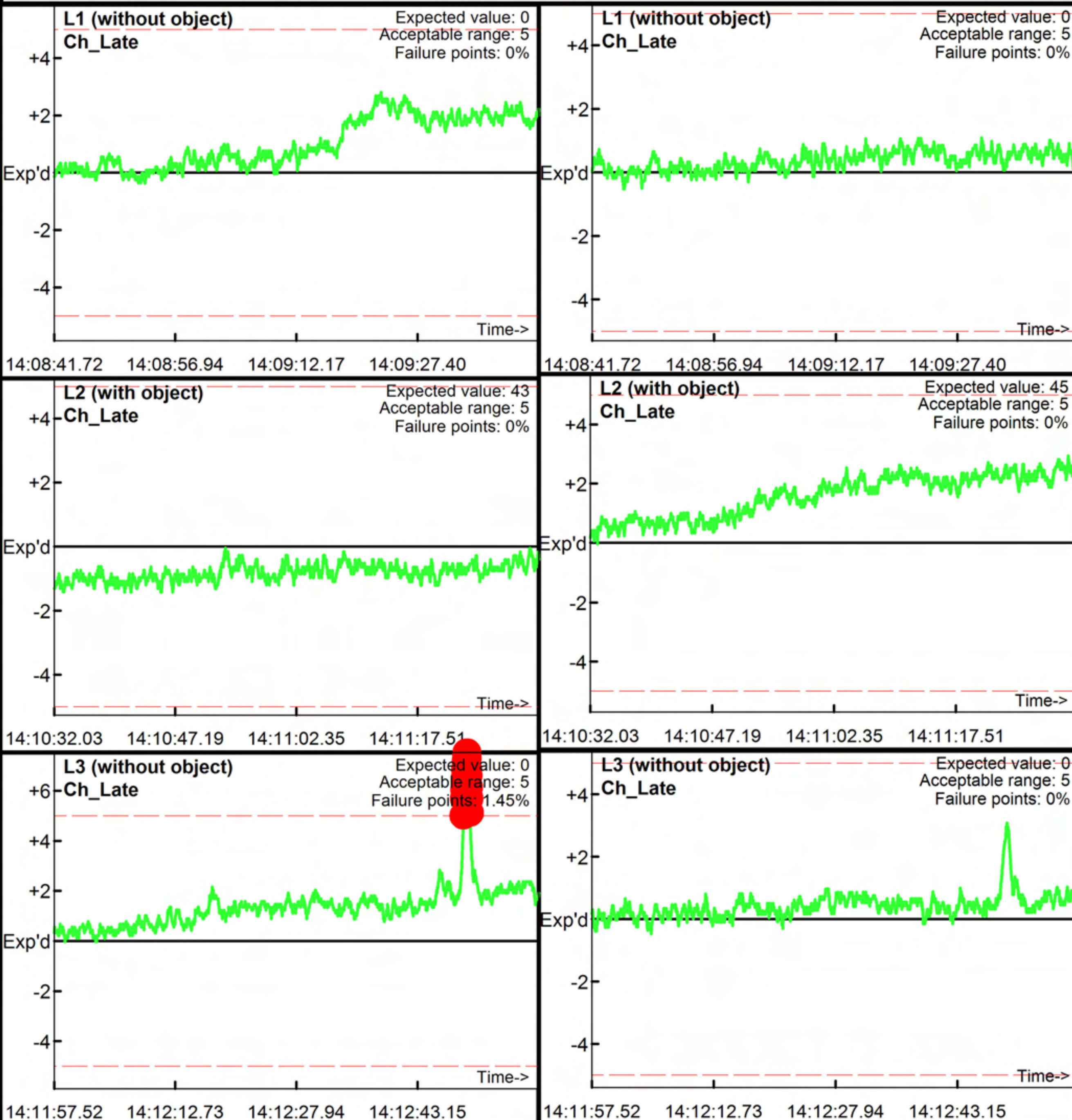
Static Calibration Test

Project: Camp LeJeune Shallow Water UXO Survey
Equipment: Underwater UXO Towed Array

Allowable failure (%): 5%
Outside range
Acceptable limits

Operator: EK
Date: 6/9/2010

Coil 1 Coil 2



Database: C:\GeoSoft-Static_QC\static_060910_L.gdb
Line Name: L1 L2 L3

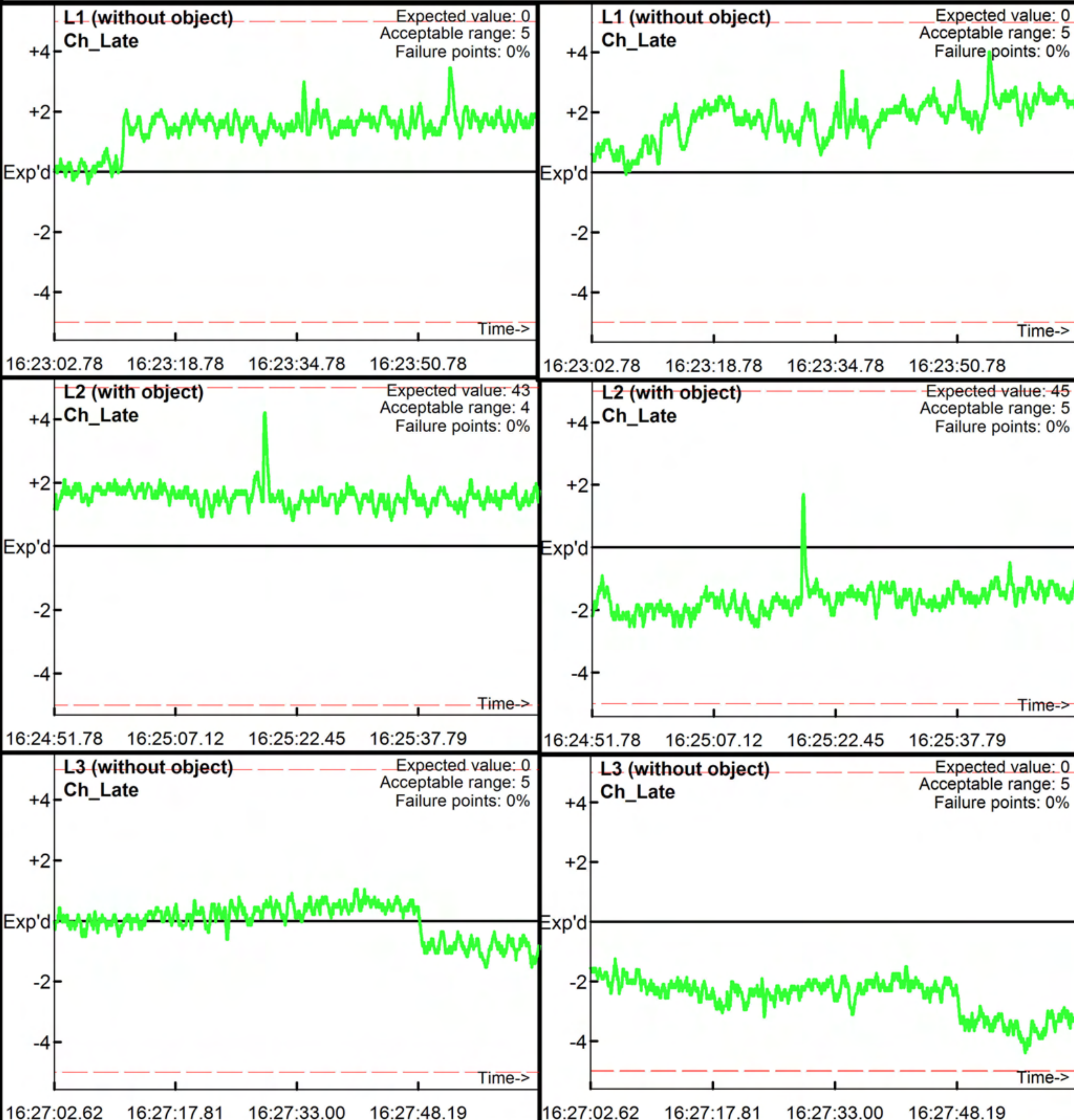
Static Calibration Test

Project: Camp LeJeune Shallow Water UXO Survey
Equipment: Underwater UXO Towed Array

Allowable failure (%): 5%
Outside range
Acceptable limits

Operator: EK
Date: 6/11/2010

Coil 1 | Coil 2



Database: C:\GeoSoft-Static_QC\static_060911_L.gdb
Line Name: L1 L2 L3

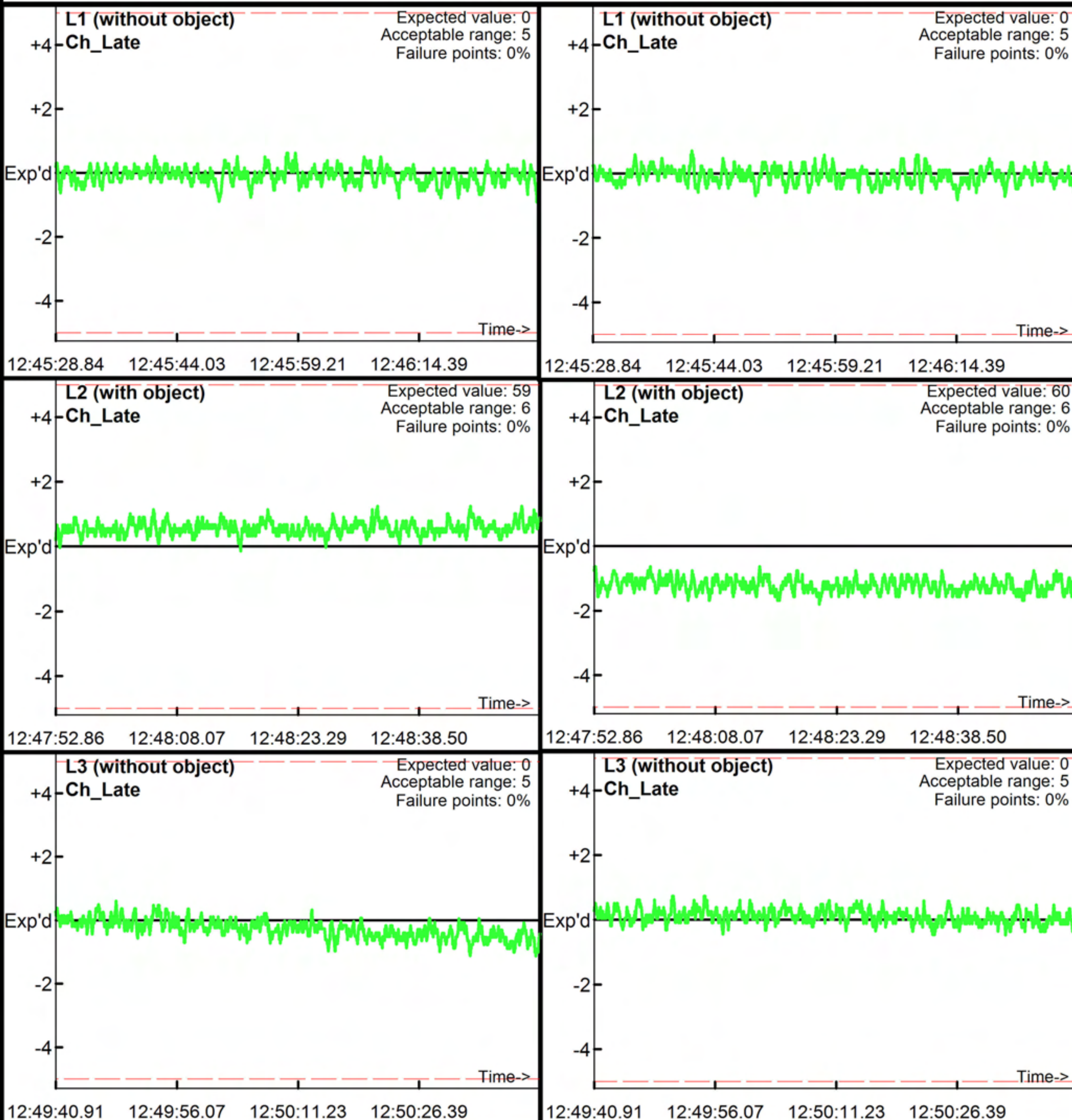
Static Calibration Test

Project: Camp LeJeune Shallow Water UXO Survey
Equipment: Underwater UXO Towed Array

Allowable failure (%): 5%
Outside range
Acceptable limits

Operator: EK
Date: 6/14/2010

Coil 1 | Coil 2



Database: C:\GeoSoft-Static_QC\static_060914_L.gdb
Line Name: L1 L2 L3

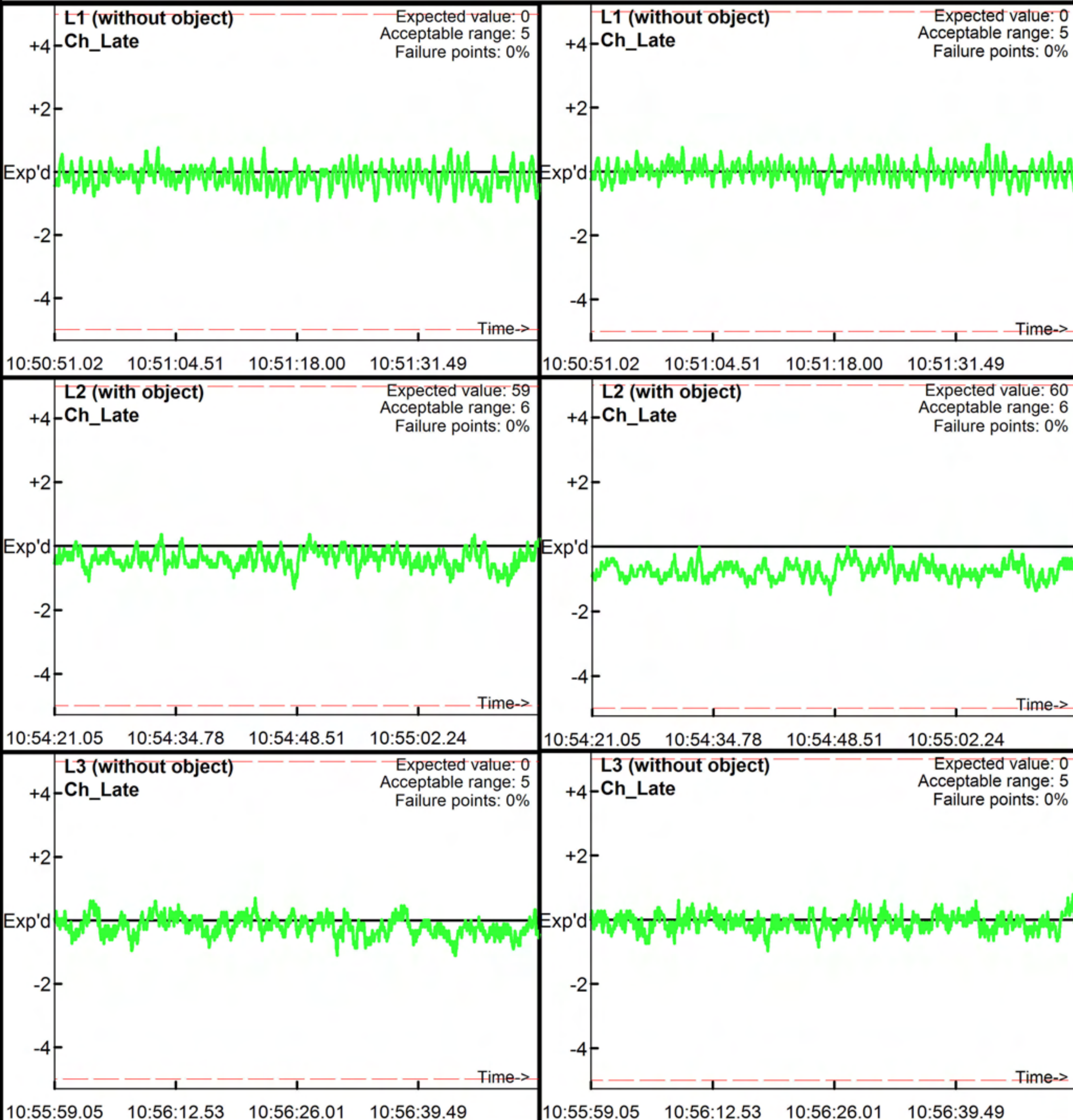
Static Calibration Test

Project: Camp LeJeune Shallow Water UXO Survey
Equipment: Underwater UXO Towed Array

Allowable failure (%): 5%
Outside range
Acceptable limits

Operator: EK
Date: 6/15/2010

Coil 1 Coil 2



Database: C:\GeoSoft-Static_QC\static_060915_L.gdb
Line Name: L1 L2 L3

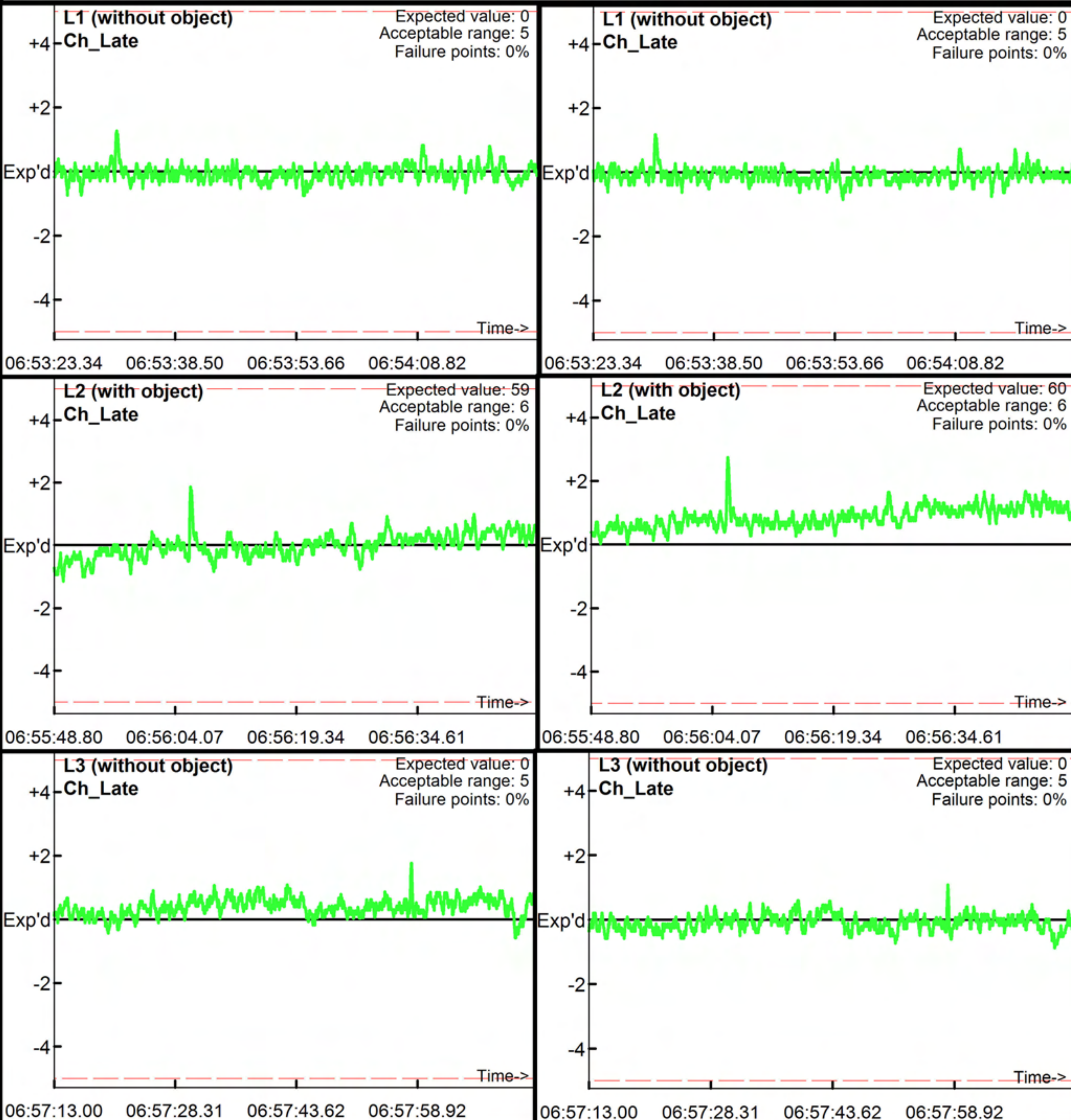
Static Calibration Test

Project: Camp LeJeune Shallow Water UXO Survey
Equipment: Underwater UXO Towed Array

Allowable failure (%): 5%
Outside range
Acceptable limits

Operator: EK
Date: 6/16/2010

Coil 1 | Coil 2



Database: C:\GeoSoft-Static_QC\static_060916_L.gdb
Line Name: L1 L2 L3

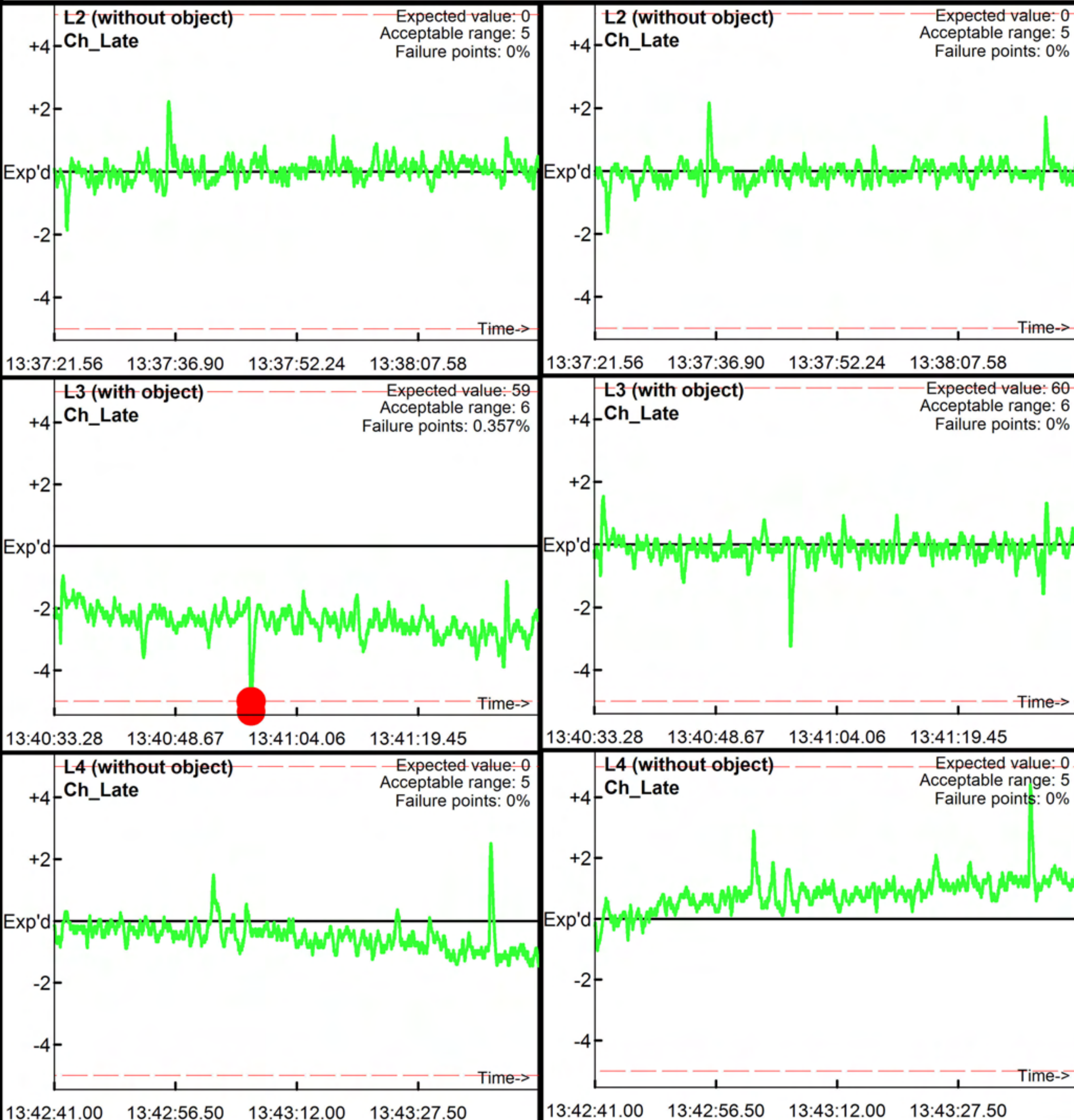
Static Calibration Test

Project: Camp LeJeune Shallow Water UXO Survey
Equipment: Underwater UXO Towed Array

Allowable failure (%): 5%
Outside range
Acceptable limits

Operator: EK
Date: 6/19/2010

Coil 1 | Coil 2



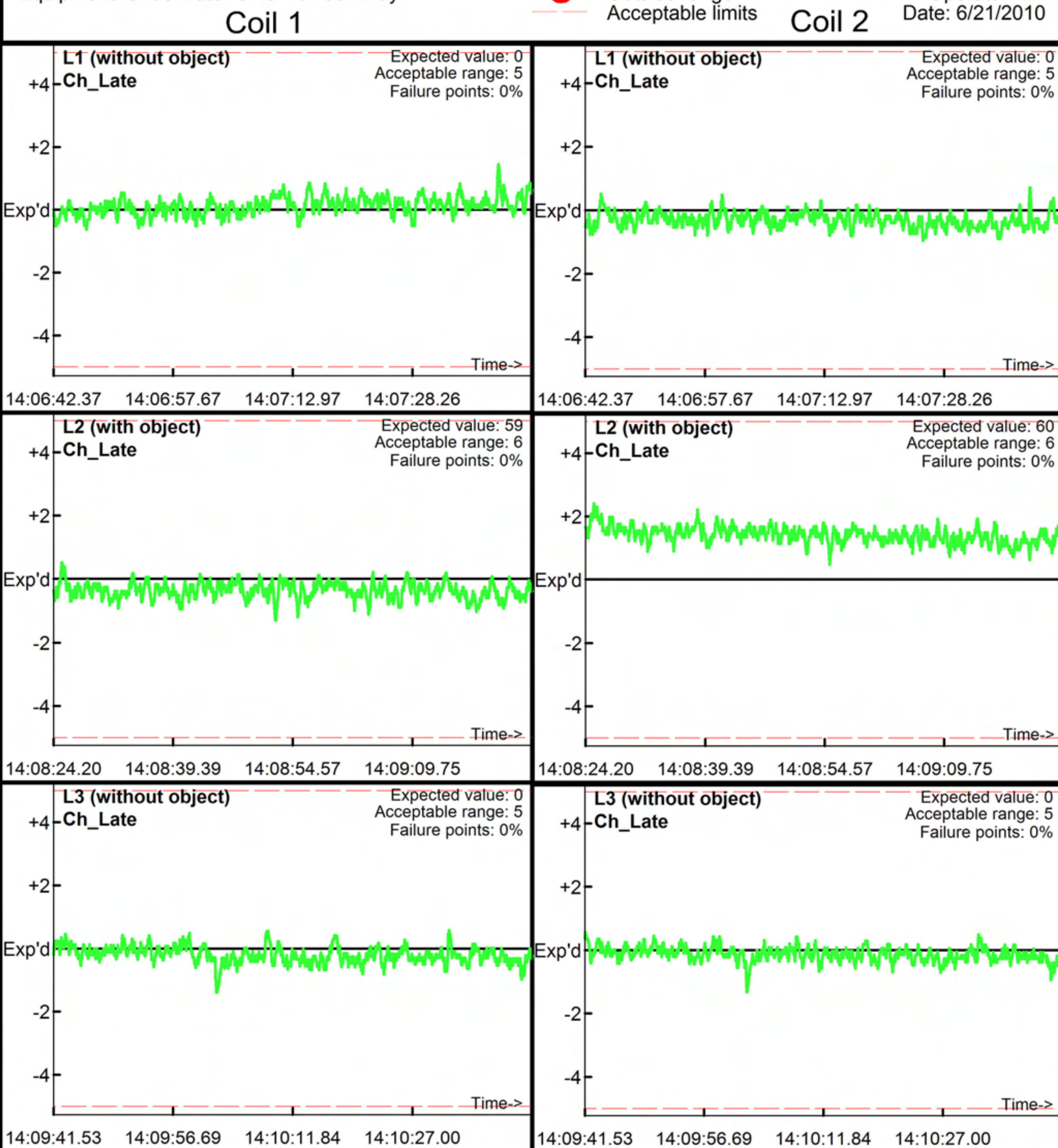
Database: C:\GeoSoft-Static_QC\static_060919_L.gdb
Line Name: L2 L3 L4

Static Calibration Test

Project: Camp LeJeune Shallow Water UXO Survey
Equipment: Underwater UXO Towed Array

Allowable failure (%): 5%
Outside range
Acceptable limits

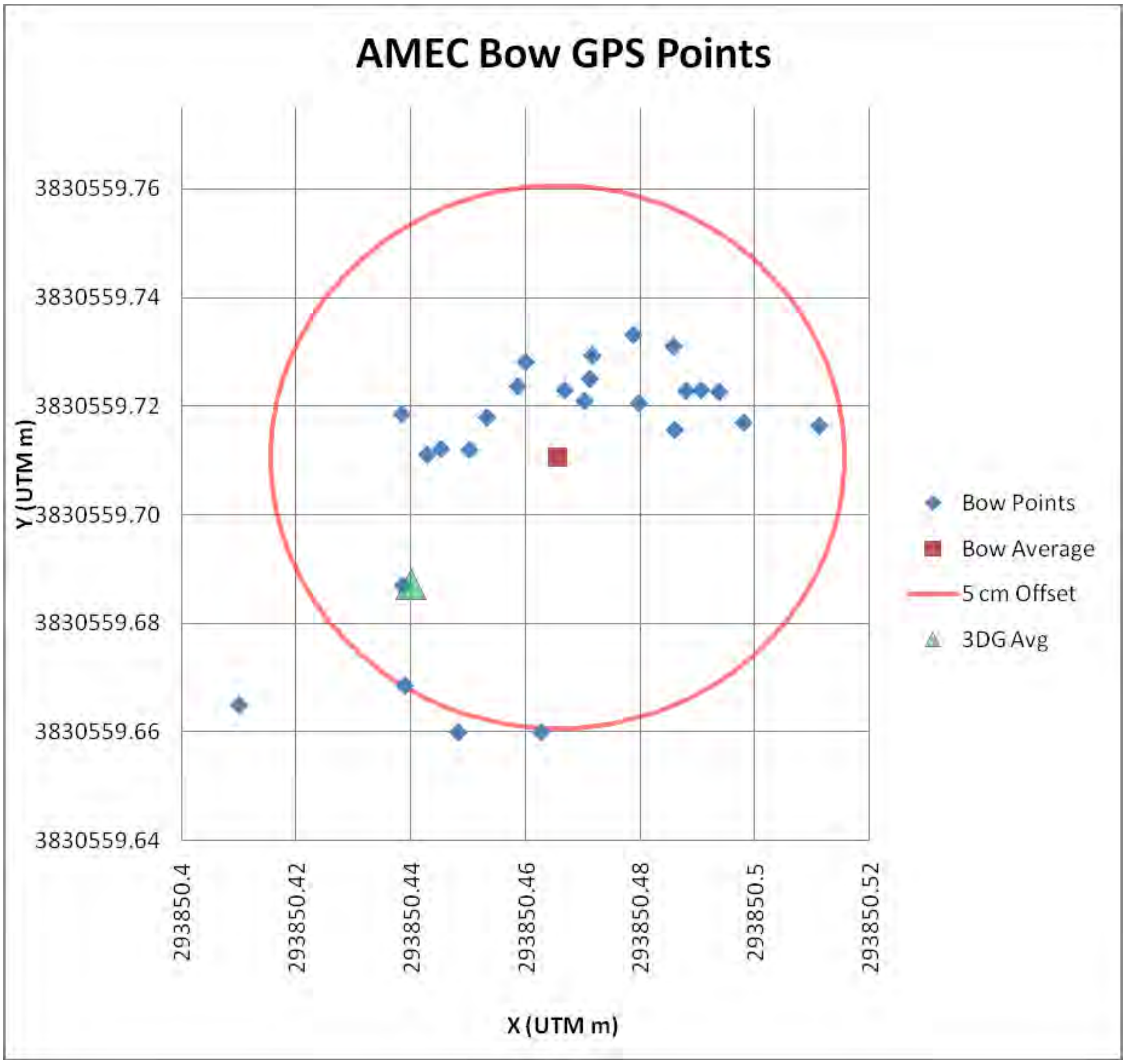
Operator: EK
Date: 6/21/2010



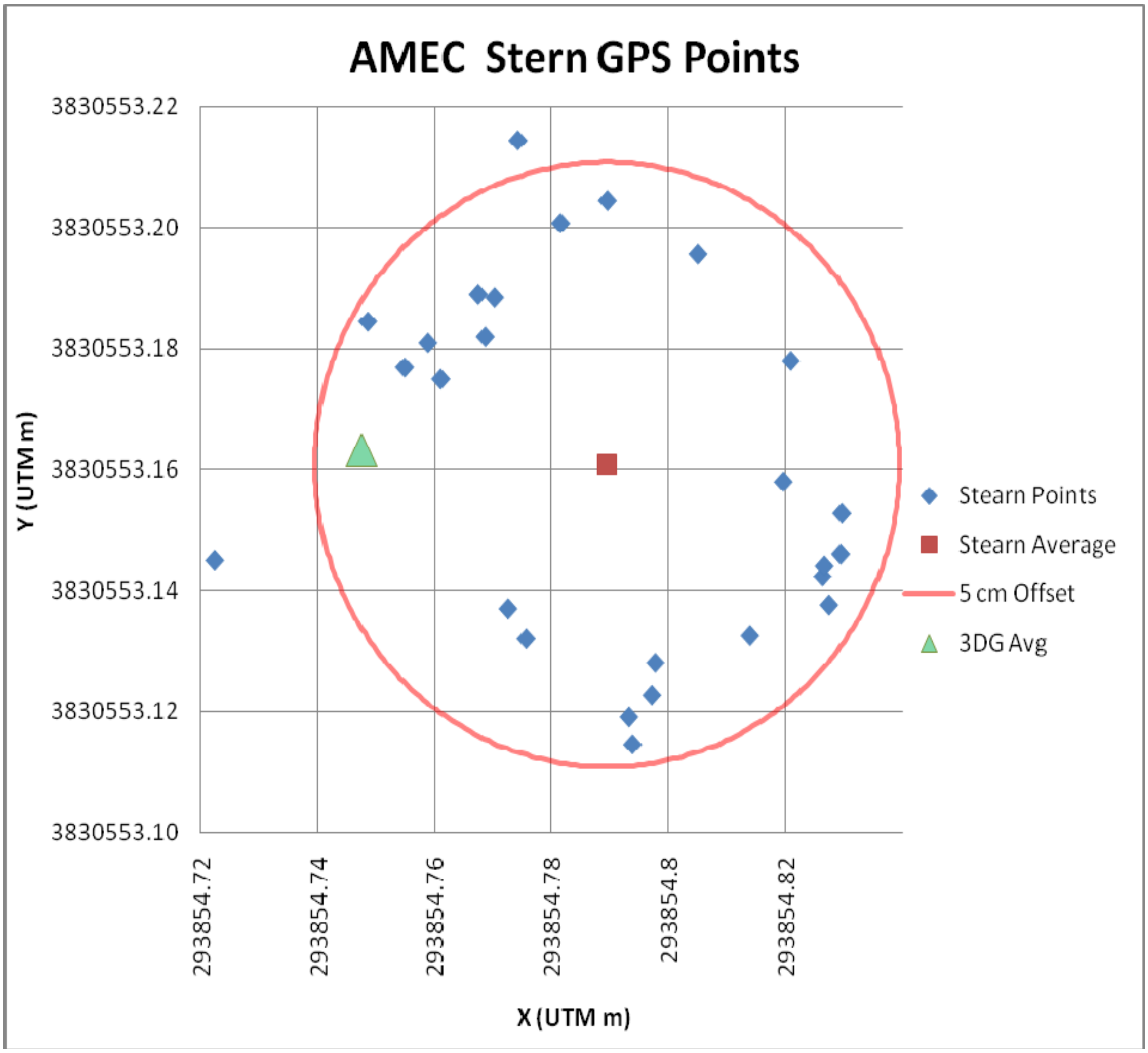
Database: C:\GeoSoft-Static_QC\static_060921_L.gdb
Line Name: L1 L2 L3

APPENDIX C

GPS Test Results



AMEC Bow GPS Points
3830559.76
3830559.74
3830559.72
3830559.70
3830559.68
3830559.66
3830559.64
Y (UTM m)
293850.4
293850.42
293850.44
293850.46
293850.48
293850.5
293850.52
X (UTM m)
Bow Points
Bow Average
5 cm Offset
3DG Avg


AMEC Stern GPS Points
3830553.22
3830553.20
3830553.18
3830553.16
3830553.14
3830553.12
3830553.10
Y (UTM m)
293854.72
293854.74
293854.76
293854.78
293854.8
293854.82
X (UTM m)
Stearn Points
Stearn Average
5 cm Offset
3DG Avg